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OF THE

Royal Geological Society

OF

CORNWALL;

INSTITUTED FEBRUARY 11th, 1814.

JANY 1873

VOLUME THE EIGHTH—PART THE SECOND.

"A knowledge of our subterranean wealth would be the means of furnishing greater opulence to the country, than the acquisition of the mines of Mexico and Peru."

President of the Board of Agriculture.

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Observations on Subterranean Temperature.

By WILLIAM JORY HENWOOD, F.R.S.; F.G.S.;

MEMBER OF THE GEOLOGICAL SOCIETY OF FRANCE;
PRESIDENT OF THE ROYAL INSTITUTION OF CORNWALL;
SOMETIME HER MAJESTY'S ASSAY-MASTER OF TIN IN THE DUCHY OF CORNWALL;

MEMBER OF THE SOCIETY.

The first series of results* recorded in the following columns, was obtained in an absolutely dry†—though a deep—mine, by placing the thermometers in holes which had sometime before been purposely bored in the several limestones;* all others were determined in streams of water immediately as they issued‡ from the various rocks and veins.

---

* *Postea*, p. 725.

† "It is in the solid rock that the best observations, and those most suited to the purpose of philosophical reasoning, are to be obtained."

PHILLIPS, *Reports of the British Association*, v. (1836), p. 292.

‡ "I am disposed to attach most importance to observations on springs of water, not coming from the roofs of galleries, or evidently proceeding from higher parts of the mines."—FOX, *Cornwall Geol. Trans.*, III. p. 320.

"After most careful consideration of the subject, and consultation with others who have also been engaged in this enquiry, it has been thought best to confine the observations, as much as possible to the temperature of the streams of water immediately issuing from the unbroken portions of the rocks and veins. The reasons for this preference are;—that the temperature of the *air* in mines is affected, not only by the presence of the workmen, the combustion of candles, and the explosion of gunpowder, but also by the warm or cold air which is brought to the same spot by the varying directions of the currents underground, which are more or less influenced by the changes of wind at the surface; that the *rocks*, forming the sides of the shafts and levels, must, to a certain extent, partake of the temperature of the air circulating through them, and, of course, be affected by its changes;—and that the *water* flowing through, or standing in pools in the levels, is exposed to the same modifying causes, and probably also, warmed by the workmen who frequently stand in it."

HENWOOD, *Ibid*, v. pp. 387—8.

CHILI.

PROVINCE OF ATACAMA.—DEPARTMENT OF COPIAPÓ

DISTRICT OF CHAÑARCILLO. Long. 70° 30′ W., Lat. 27° 15′ S.

Mine of *Colorada*.* Elevation of the surface about 3,650 feet above the Pacific; † 1,750 feet above the plain. ‡

The first,——third,——and fifth strata are of limestone; §
„ second,——and fourth—— „ „ hornblendic rocks.§

The *lodes* yield silver and many of its ores in great abundance; beside iron-pyrites and blende in smaller proportions.‖

The extremes of temperature during the year have been considered 52°—68°; ¶
„ mean „ „ has been estimated at about .... 64°.**
The range „ from the 9th to the 15th of June, 1857,..... was 39°·5-66°·5; ††
„ mean „ „ „ about .... 48°·5.††

---

* *Ante*, p. 90; *Table III.; Pl. I., II.*

† Domeyko, *Annales des Mines*, 4me Série, IX. p. 433. Henwood, *Reports of the Royal Institution of Cornwall*, XXXIX. p. 15; *Edin. New Phil. Journal*, VII. N.S. p. 147.

‡ Henwood, *Reports of the Royal Institution of Cornwall*, XXXIX. p. 15; *Edin. New Phil. Journal*, VII. N.S. p. 147.

§ Domeyko, *Annales des Mines*, 4me Série, IX. pp. 435—40. *Ante*, pp. 69, 79.

‖ Domeyko, *Annales des Mines*, 4me Série, IX. pp. 441—53. *Ante* pp. 86—118.

¶ "Le climat de cette montagne est très-doux et tempéré; mais il n'y pleut que tous 8 à 9 ans. * * * Il est rare que le thermomètre y monte à plus de 20° C. [68° F.] à l'ombre, et qu'il descende au dessous de + 9° [52° F.]."
DOMEYKO, *Annales des Mines*, 4me Série, IX. p. 433.

** Keith Johnston, *Atlas of Physical Phænomena, Pl. XVIII.*

†† Temperature in the shade at the surface of the *Colorada* mine:—

Date.	7 A.M.	9 A.M.	NOON.	3 A.M.	6 P.M.	9 P.M.
	°	°	°	°	°	°
1857, June 9th	58·5	62·8				
„ „ 10th	..	61·	66·5	61·6	56·5	50·5
„ „ 11th	..	46·8	53·8	..	..	48·3
„ „ 12th	44·	45·				
„ „ 13th	39·5	43·8	..	..	44·	42·
„ „ 14th	39·8	42·	48·	46·	42·	41·8
„ „ 15th	42·8	43·8				
Highest	58·5	62·8	66·5	61·6	56·5	50·5
Lowest	39·5	42·	48·	46·	42·	41·8
Means	44·9	49·3	56·1	53·8	47·5	45·8

The stations at which observations were made, and the temperatures observed underground, were the following:—

Locality.	Depths. fms.	Temperature of rock, in hole 3 feet deep.	Temperature of air circulating through the mine at the same spot.
		°	°
1st Limestone; between *Waring's lode* on the E. and the *Colorada lode* on the W.	46·	64·8	66·
2nd Limestone; " "	127·	67·5	66·75
" " ; at the bottom of the shaft	150·	67·*	66·
3rd Limestone; E. side *(wall)* of the *Colorada lode* .... an unfrequented part of the mine	227·	72·	76·
" " ; " : a frequented part of the mine	"	74·5	76·5

BRAZIL.

PROVINCE OF MINAS GERAËS,—DISTRICT OF RIO DAS VELHAS,—
PARISH OF CONGONHAS DE SABARA'; Long. 43° 50′ W., Lat. 19° 58′ 20″ S.

Mine of *Morro Velho.*† Elevation of the surface about 3,250 feet above the sea.

Wrought in clay-slate.

"If, in the absence of observations at midnight, and at 3 a.m., we assume the mean temperatures at those hours to have been 45°, which at this season cannot be wide of the truth; we have an average of about 48°·5 during the twenty-four hours.

"On the 11th of June the thermometer stood at 53°·8 in the shade at noon.
" " 66°·8 " sunshine " .
"On that day and on the 15th of June much rain fell."

HENWOOD, *Reports of the Royal Institution of Cornwall*, XXXIX. p. 15; *Edin. New Phil. Journal*, VII. N.S. p. 148.

* "This observation, made at the bottom of the shaft, where the draught was very great, ought, perhaps, to be excluded from the general average."—*Ibid.*

† Von Eschwege, *Pluto Brasiliensis*, t XVI. Caldcleugh, *Travels in Brazil*,

The metalliferous deposit affords enormous quantities of auriferous iron-pyrites, beside much smaller proportions of arsenical-pyrites and copper-pyrites;* in vein-stones of quartz and quartzose slate.†

From July, 1868, to June, 1869, the temperature at the surface ranged from 40° to 86°, and averaged 66°·84.‡

The temperatures in the same, and in different, parts of the mine § at various times, are shown in the following columns:—

Localities.	Depth. Fathoms.	Localities.‖ Bahù.‖ Periods. 1843.* December.	1863.¶ July.	1864.¶ January.	Cachoeira.‖ Periods. 1843.* December.	1863.¶ July.	1864.¶ January.
		Temperatures.					
Water issuing from the pumps	12·	..	64·	68°·75	..	65°·12	69°·25

II. pp. 271—4. von Spix und von Martius, *Reise en Brasilien*, II. pp. 417—18. Saint Hilaire, *Voyage dans le district des Diamans*, I. p. 169. Gardner, *Travels in Brazil*, p. 496. Claussen, *Bulletins de l'Académie Royale de Bruxelles*, VIII. 1re partie, p. 323. Whitney, *Metallic Wealth of the United States*, pp. 111—12. Burton, *Exploration of the Highlands of the Brazil*, I. p. 251. Phillips (J. A.), *Mining and Metallurgy of Gold and Silver*, pp. 80—3, 210—20. Henwood, *Cornwall Geol. Trans.*, VI. p. 143; *London, Edinburgh, and Dublin Phil Mag.*, 3rd Series, XXV. p. 343; *Ante*, pp. 184—209.

* Henwood, *Cornwall Geol. Trans.*, VI. p. 144; *London, Edinburgh, and Dublin Phil. Mag.*, 3rd Series, XXV. p. 344; *Ante*, pp. 194—8.

† *Ibid.*

‡ John Hockin, Esq., Chairman of the Saint John d'el Rey Company, M.S.

§ "Temperature at 7 mètres [3·8 fms.] below the surface 20°·65 C. [69°·17 F.]
" 271·6 " [148·5 "] " 27°·22 " ." [81° "]
BURTON, *Exploration of the Highlands of the Brazil*, I. p. 251, Note.

‖ Henwood, *Cornwall Geol. Trans.*, VI. p. 144, *Pl. I.*; *London, Edinburgh, and Dublin Phil. Mag.*, 3rd Series, XXV. pp. 384; *Ante*, pp. 188—90, *Pl. III.*; *Proceedings of the Royal Geological Society of Cornwall*, 24th Oct., 1865.

¶ For these observations the writer is indebted to the cordial co-operation of

Localities.	Depths. Fathoms.	Localities. Periods. Temperatures.					
		Bahà.			*Cachoeira.*		
		1843. December.	1863. July.	1864. January.	1843. December.	1863. July.	1864. January.
Water issuing from the rock upper side (*hanging-wall*) S. of metalliferous deposit	28·5	° ..	° 64·5	° 66·	°	°	°
" metalliferous deposit .	45·	68·*	..	..	69·*		
" rock lower side (*foot-wall*) N. of metalliferous deposit	58·6	..	..	67·			
" " ..	77·	..	..	..	..	..	69·16
" rock upper side (*hanging-wall*) S. of metalliferous deposit	145·	..	..	..	..	..	72·*
" " ..	150·	..	..	..	..	..	70·8
" metalliferous deposit .	155·	..	..	..	..	72·*	72·*
Water collected at the bottom of the Engine-shaft	160·	..	65·	69·5	..	69·05	71·5

PARISH OF CAETHÉ; Long. 43° 30′ W., Lat. 19° 58′ 30″ S.

Mine of *Gongo Soco.*† Elevation of the surface about 3,360 feet above the sea.

J. N. Gordon, Esq., Resident Superintendent of the mine, and to the kindness of John Hockin, Esq., Chairman of the Saint John d'el Rey Mining Company.

* "At the celebrated gold-mine of Morro Velho, in Brazil, situate at a height of 3250 feet above the sea, and opened in clay-slate; the water issuing from the rock at 45 fathoms depth, observed in 1843, had a temperature of 69°; that at the bottom of the mine in 1863 and 1864, at 145 and 155 fathoms deep 72°. These temperatures were quite independent of the warm rains a little before and after Christmas, which make themselves felt all the way down the engine-shafts."—SMYTH (Presidential Address to the Geological Society of London in 1868), *Quarterly Journal of the Geological Society*, XXIV, p. lxxxvi., Note.

† Von Eschwege, *Pluto Brasiliensis*, pp. 311—44. Gardner, *Travels in Brazil*, p. 491. Claussen, *Bulletins, de l'Académie Royale de Bruxelles*, VIII. 1re Partie, p. 327. Whitney, *Metallic Wealth of the United States*, p. 111. Phillips (J. A.), *Mining and Metallurgy of Gold and Silver*, p. 84. *Ante*, pp. 248—96, *Pl. IV.*

Wrought, for the most part, in *(Jacotinga* *) iron-glance mixed with black, brown, and yellowish earthy iron-ore, as well as with friable black manganese and both buff-coloured and pearl-white talc; in some places, however, the iron-glance is replaced by quartz.

From (9,459) observations, made at intervals of three hours, it was ascertained, that during 1845, 1846, and 1847 the temperature, at the surface, ranged from 40°·8 to 91°·7, and averaged about 66°·5.†

Streams issuing from the ground have, at different times, been found of the undermentioned temperatures.

Localities.	Depths. fms.	Temperatures. 1843. October.	Temperatures. 1845. July.
The water issuing from a low hill S. of the valley,—passes through an ancient, long-abandoned, drift,—some 20 fathoms above the horizon of the *adit* (48 fathom) *level* ‡ in the mine, and supplies a well (which is protected from both direct and reflected sunshine) ..... varied at different times ..	..	..	67·3–68·
Water issuing from the pumps at the (48-fm.) *adit level* ‡	34·‡	67·	
" " " " ‡	..	..	67·
" " auriferous *(Jacotinga)* formation	..	..	67·1
" ; a large stream out of earthy brown iron-ore and quartz, which represents the auriferous *(Jacotinga)* formation, E.	41·	68·	66·6

* von Eschwege, *Pluto Brasiliensis*, p. 311. Hocheder, *Report of the Imperial Brazilian Mining Association*, xv. p. 54. Henwood *Cornwall Geol. Trans.*, vi. pp. 227,—94; *Ante*, pp. 214,—19,—21,—3,—8,—42,—4,—6,—54,—6,—8,—63,—5.

† Henwood, *London, Edinburgh, and Dublin Phil. Mag.*, 3rd Series, xxviii. pp. 364—8; xxx. pp. 361—4; xxxii. pp. 422—5; *Table* XXX.

‡ This drift is 48 fathoms deep at *Lyon's* shaft, but is
only 34 " " *Veseys* (Engine) shaft.
Ante, Table VIII., Note *d*; *Pl. IV.*, Fig. 1, 2.

Localities.	Depths. fms.	Temperatures. 1843. October.	1845. July.
Water, a small stream from iron-glance and quartz (*Itabirite*) overlying the auriferous (*Jacotinga*) formation	41·	67·5	67·
" , " out of " ..	48·	67·7—68	
" , a large stream " " ..	"	..	67·
" , a moderate stream out of auriferous (*Jacotinga*) formation	"	67·7	
" , " "	62·	..	67·8
" , a large stream from between iron-glance and quartz (*Itabirite*), S., and auriferous (*Jacotinga*) formation	"	..	66·8
" , a moderate stream from iron-glance and quartz (*Itabirite*), N.	"	..	67·3

DISTRICT OF VILLA RICA.—

PARISH OF CATTAS ALTAS. Long. 43° 10′ W., Lat. 18° 50′ S.

Mine of *Agoa Quente.** Elevation of the surface about 3,400 feet above the sea.

Wrought in *Jacotinga*†, composed of quartz in unequal—but sometimes in considerable—proportions, minute crystals of oxydulated and titaniferous iron, scales of micaceous iron-ore, flakes of talc, and small nests of felspar-clay, imbedded in earthy brown iron-ore tinged, at intervals, with earthy black manganese.

During 1848—9 the temperature at the surface ranged from 42°· to 84°·8 *(Table XXXI.)* and averaged about 60°·3.‡

* Von Eschwege, *Pluto Brasiliensis*, p. 299. De Monlevade, *Annales des Mines*, IV. p. 136. Caldcleugh, *Travels in South America*, II. p. 283.

† Von Eschwege, *Pluto Brasiliensis*, t IV. p. 299. *Ante*, pp. 224—36.

‡ Notwithstanding the monthly means at *Agoa Quente*, between October, 1848,

The undermentioned observations were made at times when very different quantities of rain-water *—absorbed at the surface—found their way into the mine; and when the works were opened at different depths.

Localities.	Depth. fms.	1844. May.	1847. Nov.	1849. Jan.	1849. Apr.	1849. June.
Water in a brook at the surface	..	..	68°	76°	°	°
" out of the *back* of the *(level)* drift at the *end*.	4·5	..	..	73.		
" " " 2 feet from " .	"	..	..	76·		
" " " 3 " " .	"	..	..	74·		
" out of ancient—& long-abandoned—works.	6·	..	70·2			
" , small stream out of *(Itabirite)* rock S. side *(wall)* of auriferous *(Jacotinga)* formation	7·	92·				
" out of ancient-& long-abandoned-works (*a*)	8·	72·				
" , large streams jetting out of auriferous *(Jacotinga)* formation, and *(Itabirite)* rock on both *(walls)* sides of it.....	10·	91·5				
" , small stream out of auriferous *(Jacotinga)* deposit (*a*)	12·	..	..	80·7		
" , large stream, bottom of an Engine-shaft .	15·	..	88·			
" , " " a second " .	"	..	96·5			
" , " " " " .	18·	..	..	91·		
" , " out of auriferous *(Jacotinga)* formation at the bottom of an Engine-shaft	24·	..	..	85·		

and July, 1849 *(Table XXXI.)*, differed somewhat from those at *Gongo Soco* during 1845—7 *(Table XXX.)*; the general average, for corresponding periods, coincided within 0°·3.

* The rain which fell at *Agoa Quente* during the same period was

1848, October	3·28 inches.	1849, March	16·86 inches.
" , November ..	12·08 " .	" , April	7·98 " .
" , December ..	24·80 " .	" , May	8·14 " .
1849, January	15·10 " .	" , June.....	0·88 " .
" , February....	19·86 " .	" , July.....	— " .
Total.....		108·98 inches,	

Localities.	Depth. fms.	1844. May.	1847. Nov.	1849. Jan.	1849. Apr.	1849. June.
		°	°	°	°	°
Water, large stream out of auriferous *(Jacotinga)* formation, both E. and W.	26·	..	..	..	90·5	
" , small stream out of auriferous *(Jacotinga)* formation	28·	..	..	..	..	77.8
" , " " within one foot of that last mentioned.	"	..	..	..	..	78·3
" , " out of *(Itabirite)* rock S. side *(wall)* of auriferous *(Jacotinga)* formation	"	..	..	..	..	89·3
" , large stream out of auriferous *(Jacotinga)* formation	"	..	..	..	..	88·
" , " " , within nine feet of that last mentioned....	"	..	..	..	..	92·
" , " bubbling up out of auriferous *(Jacotinga)* formation....	29·	..	..	..	92·5	
" which filled the mine to within 4·5 fms. of the surface, during a stoppage of the pumps; at one spot	15·	..	82·3*			
" " " at a second spot	"	..	83·3*			
" drawn by pumps to the surface at one shaft (*b*) from	9·	..	81·9			
" " " a second " (*c*) "	"	..	84·			
" " " one shaft (*b*) "	10·	84·				
" " " a second " (*c*) "	"	87·				
" drawn by pumps to the *adit* (14 fathoms deep) at one shaft (*c*) "	18·	..	..	91·		
" " " another " (*b*) "	24·	..	..	83·5		
" " ..... "	29·	..	..	..	91·5	

* Fish throve in this water. *Ante*, p. 355.

The power of fishes to bear extremes of temperature is well known.

YARRELL, *History of British Fishes*, I. pp. 316—19. COUCH, *Fishes of the British Islands*, IV. p. 33.

PARISH OF INFICIONADA; adjoining CATTAS ALTAS.

Mine of *Fraga** or *Ouro Fino*. Elevation of the surface about 3,300 feet above the sea.

Wrought in that part of the talcose-slate series which overlies the (*Jacotinga*) manganesic iron-glance formation.

As *Fraga* is so near *Agoa Quente* and *Gongo Soco*, it, probably, differs little in climate, from them; but, inasmuch as it is less enclosed than they are by mountains and woods, its mean temperature may, perhaps, be somewhat cooler than theirs; on this, however, reliable observations have never been recorded.

The undermentioned temperatures have been observed:—

A large stream as it issues from the auriferous talc-slate into a (adit-*level*) drift opened from the vale	..... 69°.
" drawn by pumps to the surface from a depth of 21 fms.	.. 70°·5

THE UNITED STATES.

STATE OF VIRGINIA,—COUNTY OF BUCKINGHAM.
Long. 78° 30′ W., Lat. 37° 35′ N.

The *Garnett* and *Moseley*† mines have been wrought in chloritic, micaceous, and talcose slates, on a broad conformable bed of quartzose, felspathic, calcareous, and slaty matter, mixed with considerable quantities of earthy brown iron-ore near the surface, and of iron-pyrites at greater depths, as well as with smaller proportions of gold.

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* Von Eschwege, *Pluto Brasiliensis*, t v. *Ante*, pp. 301,—23.

† Rogers, *Geological Reconnoissance of Virginia*, p. 63. Ansted, *Scenery Science, and Art*, pp. 288—90. *Ante*, pp. 379—84.

The line of 55° mean annual temperature passes within a short distance of this district, if not directly through it.*

A small stream pumped to the surface from a depth of 15·5 fathoms maintained, during September, 1852, a temperature of 56°.8†

STATE OF MICHIGAN,‡—COUNTY OF ONTONAGON (Long. 89° 30′ W., Lat. 46° 50′ N.).

The rains which immediately precede the first snows freeze almost as soon as they soak into the ground whilst the floods of autumn, which had been already absorbed, are—under influence of cold air, descending from the surface and circulating through the mines,

* Keith Johnston, *Atlas of Physical Phenomena, Pl. XVIII.*

† On the 4th of September, 1852, the temperature at the surface about 6 p.m. was 76°.2.

‡ The following temperatures were observed in the Keweenaw district from (two hundred to four hundred feet above Lake Superior) eight hundred to a thousand feet above the sea; in mines wrought, in the trap formation, on *lodes* composed of calcareous-spar, prehnite, quartz, epidote, chlorite, and trappean matter. In most parts of the district some or others of these ingredients are more or less mixed with native copper, and this is frequently encrusted with virgin-silver (BAYFIELD, *Quarterly Jour. of the Geol. Soc.* I. p. 451. BAUERMAN, *Ibid*, XXII. pp. 448–63. JACKSON, *Geological and Mineralogical Reports*, Passim. FOSTER & WHITNEY, *Geological Report*, pp. 58—186. *Ante*, pp. 411—63, *Tables XII.—XIV.*).

At *Lac la Belle*			
the temperature of the air at the surface	.....	was.....	71°·
,, ,, in the upper *level*	..	,, ...	47·
,, water ,,	..	,, ...	44·
,, air at 23·3 fms. deep	..	,, ...	51·
,, water ,, ,,	..	,, ...	44·
,, air 30· ,,	..	,, ...	48·
,, water ,, ,,	..	,, ...	45·
At *Copper Falls*—			
the temperature of the air at the surface	..	was.....	42·
,, water at 3·3 fms. deep	..	,, ...	44·5
,, air ,, 20· ,,	..	,, ...	49·
,, water ,, ,, ,,	..	,, ...	44·5

PARISH OF INFICIONADA; adjoining CATTAS ALTAS.

Mine of *Fraga** or *Ouro Fino*. Elevation of the surface about 3,300 feet above the sea.

Wrought in that part of the talcose-slate series which overlies the (*Jacotinga*) manganesic iron-glance formation.

As *Fraga* is so near *Agoa Quente* and *Gongo Soco*, it, probably, differs little in climate, from them; but, inasmuch as it is less enclosed than they are by mountains and woods, its mean temperature may, perhaps, be somewhat cooler than theirs; on this, however, reliable observations have never been recorded.

The undermentioned temperatures have been observed:—

A large stream as it issues from the auriferous talc-slate into a (adit-*level*) drift opened from the vale	..... 69°.
„ drawn by pumps to the surface from a depth of 21 fms.	.. 70°·5

THE UNITED STATES.

STATE OF VIRGINIA,—COUNTY OF BUCKINGHAM.
Long. 78° 30′ W., Lat. 37° 35′ N.

The *Garnett* and *Moseley*† mines have been wrought in chloritic, micaceous, and talcose slates, on a broad conformable bed of quartzose, felspathic, calcareous, and slaty matter, mixed with considerable quantities of earthy brown iron-ore near the surface, and of iron-pyrites at greater depths, as well as with smaller proportions of gold.

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* Von Eschwege, *Pluto Brasiliensis*, t v. *Ante*, pp. 301,—23.

† Rogers, *Geological Reconnoissance of Virginia*, p. 63. Ansted, *Scenery Science, and Art*, pp. 288—90. *Ante*, pp. 379—84.

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* Keith Johnston, *Atlas of Physical Phenomena, Pl. XVIII.*

† On the 4th of September, 1852, the temperature at the surface about 6 p.m. was 76°.2.

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At *Lac la Belle*			
the temperature of the air at the surface		was	71°
„	„ in the upper *level*	„	47·
„	water „	„	44·
„	air at 23·3 fms. deep	„	51·
„	water „ „	„	44·
„	air 30· „	„	48·
„	water „ „	„	45·
At *Copper Falls*—			
the temperature of the air at the surface		was	42·
„	water at 3·3 fms. deep	„	44·5
„	air „ 20· „	„	49·
„	water „ „ „	„	44·5

during winter * —often frozen as they issue, at considerable depths, from the rocks and *lodes* through which they had percolated. Thus, the streams which had entered at *Toltec* mine,† at 16·6 and at 23·3 fathoms, and the *Douglas Houghton (Henwood)* ‡ mines at 36 fathoms from the surface, during the autumn of 1855 and become frozen during the succeeding winter, were yet unthawed in the following July.

THE CHANNEL ISLANDS.

SARK.

The metalliferous rocks of Sark consist, in great measure, of felspar and hornblende,§ associated with

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At the *North American* mine—

| | | |

smaller proportions of several other substances. The *lodes* which traverse them contain great quantities of the same ingredients; mixed, largely, with quartz and calcareous-spar, and, less plentifully, with earthy brown iron-ore, iron-pyrites, and yellow copper-ore. At the S.S.W. extremity of the island, however, the *Sark's-Hope lode* afforded also argentiferous and antimoniated galena, the super-sulphuret, sulphate, sulphato-tricarbonate, and carbonate of lead, together with the chloride of silver, earthy black silver-ore, as well as vitreous, red, and native silver,* where it was wrought beneath the sea.

The temperature of Sark is probably much the same as that of Guernsey, which ranges from 24°·5 to 83°,† and averages 51°·6.‡

The undermentioned temperatures were observed at different depths in various parts of the island:—

Windmill Hill.	Depth.		Temp.
Well of fresh water (1841, January 26th§)	Surface.	.....	47°·‖
Port ès Sées.	Depth below the surface. fms.	Relation to the sea-level. fms.	
Small stream of fresh water, out of the rock.....	42·	16· A	55·
Large ,, ,, , ,, *lode*	54·	4· A	58·7

p. 101. Ansted, *Channel Islands*, pp. 263—6. *Ante*, pp. 530—2, *Table XVII., Fig.* 30.

* Prince, *Cornwall Geol. Trans.*, VI. p. 102. *Ante*, p. 535, *Table XVII.*

† Ansted, *Channel Islands*, p. 140.

‡ *Ibid*, p. 134.

§ From 1843 to 1858 the temperature at Guernsey during the month of January has ranged from 24°·5 to 54°·5, and averaged 43°·6.—Ansted, *Channel Islands*, pp. 134—7.

‖ "Some years ago, a level connected with mining operations then going on,

Le Pot.	Depth below the surface. fms.	Relation to the sea-level. fms.	Temp.
Moderate stream of fresh water, out of the rock..	47·	12· A*	54°·
" " " " *lode* ..	55·	4· B*	56·
Sark's Hope Mine.			
Small stream of fresh water, out of rock and *lode*..	24·	4· A	55·5
Moderate " brackish " " " rock	44·	20· B	56·2
Large " " " " " "	54·	30· B	57·2
Small " " " " *lode*	"	"	57·2
" " " " " rock W.	64·	40· A	58·
Water, brackish, pumped to the *adit* (4 fms. above the sea) ..... from	"	"	56·

HERM.

The *Herm* mines were wrought, to a depth of thirty fathoms, in rocks composed mostly of white, pinkish, buff-coloured, and greenish felspar, mixed with much hornblende, and sometimes with quartz and mica.†

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and opening out on the Port du Moulin, on the side of the island towards Guernsey, was found to remove the water from a well in D'Ixcart Bay, on the other side of the island."—ANSTED, *Channel Islands*, p. 472.

* A denotes distance above the sea-level.
B " below " .

† "A beautiful white and black granite rock forms the hard back bone [of Herm]; and may be recognized at intervals, around the coast. * * * This granite is intersected by many wide veins, extremely variable in their nature, but generally either soft or readily decaying. * * * There is one at the back of the island of very large size, running across more than one projecting headland, nearly in a south-westerly direction, consisting entirely of black micaceous rock. * * * There are other veins of soft clay, and some of decomposing greenstone. * * * Traces of copper are said to have been found in veins in the granite of Herm; and mining operations were at one time commenced. The chief mineral product of the island is, however, its granite; [but] it is hardly equal to the best black Guernsey granite for paving and curbstones."
ANSTED, *Channel Islands*, pp. 63,—6, 263.

Two *lodes* respectively—

bear 10°—15° N. of E.—S. of W.,* dip N., and measure 5—30 feet in width;
" 24° W. of N.—E. of S.,* " E., " 2—4 " " .

Both these,—and the numerous *(branches)* veins which separate from, and re-unite with, them, in various parts of their range,—also contain great quantities of felspar, hornblende, and quartz; iron-pyrites abounds, and small *(bunches)* masses of yellow copper-ore occur at intervals.

As Herm and Guernsey are but six miles apart, they can scarcely differ much in climate.†

The undermentioned observations were made in February, 1841; viz.—

	Depth below the surface. fms.	Relation to the sea-level. fms.	Temp.
Well of fresh water ‡	Surface.	10· A	48·7°
Small stream of fresh water out of *lode*	8·	2· B	49·5
Large " " rock at some distance	"	"	53·
Small " " *lode*	12·	8 B	55·2
Minute " " jetting out of *lode* within a short distance..	"	"	56·

IRELAND.

COUNTY OF WICKLOW.

The mines of *Connorree, Cronebane, Tigrony, Ballygahan,* and *Ballymurtagh* have afforded enor-

* In 1838 the Magnetic declination was about 24° W. Ross, *Phil Trans.*, CXXXIX. p. 208. SABINE, *Ibid, Pl. XIV. Ante*, p. 531, Note *.

† Ansted, *Channel Islands*, pp. 134,—7. *Ante*, p. 735. Note §.

‡ "Herm has good fresh water in natural springs, and in two places there is running water."—ANSTED, *Channel Islands*, p. 68.

mous quantities of iron-pyrites mixed with slaty matter, quartz, and various ores of copper,* from several beds of different widths which conformably interlie schistose rocks, presumed to be portions of the Silurian system.

At 3·1 † fms. above the sea at	Dublin	the annual mean temperature from 1840 ‡ to 1851 §	was 50°·3.
& „ 5·6 † „	Courtown	„ in 1851 §	

As Ovoca lies between Dublin and Courtown, it probably differs but little from them in climate.

Localities.	Depth below the surface. fms.	Relations to the sea-level. fms.	Temp. 1840. May.	Temp. 1840. Nov.
Connorree Mine.			°	°
Water, a well	Surface..	100· A	..	45·
„ a moderate stream out of clay-slate .	54·	75· A	..	49·5
„ „ the *Sulphur-course*..	„	„	..	50·
„ pumped to the surface ..... from	„	„	..	49·
Cronebane Mine.				
Water flowing from a hole bored in the *Sulphur-course*	72·	2·B	54·5	
„ pumped to the *adit* (16 fms. above the sea ..... from	92·	22·B	55·5	

COUNTY OF WATERFORD.

The mine of *Knockmahon* has been wrought, both

* Henry, *Phil. Trans.*, XLVII. pp. 500—3. *Journal des Mines*, No. XVI. pp. 80—5. Weaver, *Geol. Trans.*, V. pp. 173—8, 213—30. Haughton, *Journal of the Geol. Soc. of Dublin*, V. pp. 280—2. Smyth, *Records of the School of Mines*, I. pp. 370—97, Mahon, *The Mines of Wicklow*, pp. 35—75. *Ante*, pp. 540—69, *Table XVIII.*

† Lloyd, *Trans. Royal Irish Academy*, XXII. p. 416.

‡ *Ibid*, p. 424.

§ *Ibid*, p. 422.

inland and beneath the sea, in greyish-green, greenish-black, and mottled fossiliferous slates, interlaid by massive rocks of felspar, quartz, and chlorite, as well as by thin beds of ferruginous conglomerate.* The *lodes*—which have been very productive—consist, in great measure, of quartz, slaty matter, calcareous-spar, and chlorite, associated with earthy-brown iron-ore, iron-pyrites, earthy black copper-ore, vitreous copper, malachite, and copper-pyrites.† The *cross-veins*, which intersect both the rocks and *lodes*, are composed, mostly, of slaty-clay, and disintegrated felspar; but, at intervals, they contain spheroidal masses of quartz.‡

At Dunmore, some 12 miles E. of *Knockmahon*, the mean temperature of the year 1851 was.. 51°·6;§

& „ Waterford, „ 15 „ N.E. „ , the mean temperature from 1860 to 1868 was 50·3.‖

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* Weaver, *Geol. Trans.*, v. p. 248. Du Noyer, *Explanation to accompany Sheets* 167, 168, 178, 179 *of the Geological Survey of Ireland*, p. 57. Baily, *Ibid*, p. 24.

† Hore, *Ibid*, p. 81. Du Noyer, *Ibid*, pp. 81—2. *Ante*, pp. 594—8, *Table XIX.*

‡ *Ante*, pp. 598—9, *Table XIX.*

§ Lloyd, *Trans. Royal Irish Academy*, XXII. pp. 416,—24.

‖ Observations made at Newtown, Waterford;—

Years.	Maximum.	Minimum.	Mean.
1860	78°·	14°·	50°·
1	82·	25·	52·2
2	76·	20·	50·6
3	80·	28·	50·3
4	81·	19·	48·9
5	86·	20·	48·6
6	85·	20·	49·2
7	79·	16·	50·4
8	86·	28·	52·3
Extremes	86·	14·	
Mean	—	—	50·3

R. J. Greer, Esq., of Newtown, Waterford, MSS.

JAN. 1873

The undermentioned observations were made at *Knockmahon*;*—

	Depth below the surface. fms.	Relations to the sea-level. fms.	Temp.
Water, a well (29th April, 1840)	1·6	3. A	48°·
„ issuing from the clay-slate and the *lode* ..	16·	3. A	48·7
„ accumulating from several small streams out of the *lode*	112·	93· B	57·5
„ pumped to the adit (3 fms. above the sea) from..	„	„	50·5

COUNTY OF CORK.

The *Bearhaven* mines are opened in rocks, of the

* "Thermometers were placed, in August 1843, in the deepest part of Knockmahon Copper Mine; * * * one being sunk three feet into the rock, and another into the lode at a depth of [129 fathoms] from the surface. A thermometer * * * was hung in the gallery or level where these were placed. * * *

"These mines are in lat. 52° 8′ N. and the mean annual temperature at the surface calculated by the usual formula would, therefore, be 50°·026.

"The general average of the thermometers at the depth of [129 fathoms], and the maxima and minima, were as follows:—

In air	Average, 57°·176 ..	Maximum, 58°·5 ..	Minimum, 56°·25
„ rock or country.	„ 57·369 ..	„ 58·5 ..	„ 56·25
„ lode	„ 57·915 ..	„ 58·5 ..	„ 56·25

"Taking the temperature of the rock thus determined as the general average it shows an increase of 7°·343 for a depth of [129 fathoms], or deducting [16·4 fathoms] for the line of no variation, we have 1° for [15·3 fathoms]. It was found necessary to fix the instruments not far from being perpendicularly under the sea, the shaft being nearly on the edge of the cliff, which is here [11·6 to 12·5 fathoms] high. If therefore we should * * * consider the sea level as the surface, we shall have a depth of [116·6 fathoms] corresponding to [7°·343 or 1°=15·8 fathoms].

"It seems to be fully established * * * that there was a gradual though a slight diminution of temperature as the observations proceeded. Thus the temperatures were

during the first half of the period ..	in air 57°·613..	in the rock 57°·718..	in the *lode* 58°·000
„ the second half of the period ..	„ 56·697..	„ 57·044..	„ 57·675

OLDHAM, *Report of the British Association* (*for* 1844), II. pp. 221—2 (Abridged).

Carboniferous slate series,* composed of siliceous matter mixed with chlorite, talc, or some similar mineral; at intervals, however, they contain small quantities of the carbonate of lime; whilst all parts of them are intersected by minute veins of quartz. Near rich portions of the *lodes* they are usually lilac, pale-buff, or dove-coloured, and of thick-lamellar structure; but elsewhere they are blue and fissile. The *lodes* consist mostly of quartz, but contain also chloritic or talcose matter, beside smaller proportions of the carbonates of lime and of iron; moreover, they include angular *(horses)* masses of slate without number. Iron-pyrites, vitreous copper, and malachite occur now and then, but copper-pyrites is the prevailing ore.† A *cross-vein* —composed of slaty-clay in other parts of its range— becomes highly quartzose as it intersects the *Main* (Mountain) *lode.*‡

At Castletownsend, some 40 miles E.S.E., the mean temperature of the year 1851 was		52°·1;§
„ Cahirciveen,	„ 22 „ N.N.W., „ „ „	52·3.§

The mean annual temperature at the *Bearhaven* mines, therefore, is probably much the same.

The temperatures observed at different depths have been,—

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* Jukes & Kinahan, *Explanation to accompany Sheets* 197 *and* 198 *of the Geological Survey of Ireland*, pp. 13, 20. *Ante*, p. 602, *Table* XX.

† Smyth, *Explanations to accompany Sheets* 197 *and* 198 *of the Geological Survey of Ireland*, pp. 30—3. *Ante*, pp. 603—8, *Table* XX.

‡ *Ante*, p. 608, *Table* XX.

§ Lloyd, *Trans. Royal Irish Academy*, XXII. pp. 416,—23.

	Depths below the surface. fms.	Relation to the sea°-level. fms.	Temp.
Water oozing out of a rock N. of *Main Lode*	128·	60· B	58·5°
" " *Main lode*	140·	72· B	61·5
" pumped to the *adit* (20 fms. above the sea) } from..	"	"	56·

COUNTY OF KERRY.

The *Ardtully* mines were worked in, and between, reddish-purple, greenish-grey, yellowish-green, lead-coloured, or mottled, slates; † and greyish Carboniferous limestone in which crinoidal remains are not uncommon.‡ Small beds of slaty-clay, quartz, and earthy brown iron-ore, slightly sprinkled with iron-pyrites and yellow copper-ore, occur in the slate; § whilst irregular bands of calcareous-spar—here and there charged with grey and purple copper, slightly mixed with copper-pyrites, and enclosing, at intervals, small bodies of peculiar (? organic) character—merge, after short courses, in the limestone.‖ The principal

* Kinahan, *Explanations to accompany Sheets* 197 *and* 198 *of the Geological Survey of Ireland*, p. 20, *Fig.* 3.

† Jukes, Du Noyer, & Willson, *Explanations to accompany Sheet* 184 *of the Geological Survey of Ireland*, pp. 20—4. Haughton, *Journal of the Geological Society of Dublin*, VI. p. 210. *Ante*, pp. 613—15.

‡ Haughton, *Journal of the Geol. Society of Dublin*, VI. p. 208. Jukes, Du Noyer, & Willson, *Explanations to accompany Sheet* 184 *of the Geol. Survey of Ireland*, pp. 20—4. *Ante*, p. 613.

§ *Ante*, pp. 612,—15.

‖ Haughton, *Journal of the Geol. Soc. of Dublin*, VI. p, 213. Du Noyer & Willson, *Explanations to accompany Sheet* 184 *of the Geol. Survey of Ireland*, p. 37. *Ante*, pp. 518—19.

metalliferous deposit, however, intersects the slate in one part of its range, but separates the slate from the limestone in another. Where both sides *(walls)* are of slate shallow portions of the matrix consist of slaty clay mingled with earthy brown iron-ore, enclosing nodules of hematite, and angular masses of slate often encrusted with copper-pyrites, together with grains of purple, grey, and native copper; at greater depths siliceous slate—the principle ingredient—is frequently veined with quartz and speckled with copper-pyrites; moreover, where opposite sides of the deposit are bounded by rocks of different kinds, that portion of it which adjoins the slate—although rather richer—maintains, in other respects, its normal character; at its contact with the limestone, on the contrary, it comprehends ill-defined beds of grey limestone and calcareous spar which embed considerable quantities of grey and purple copper, with smaller proportions of copper-pyrites.*

Kenmare is about thirty miles N.N.W. of Castletownsend, and
about twenty-eight „ E. by S. of Cahirciveen;

but, inasmuch as it is less open to the ocean and more enclosed by mountains than they are, any difference between its mean temperature and theirs,† may, perhaps, be rather in defect than excess.

Whilst the *Ardtully* mines were deepened, observa-

* Haughton, *Journal of the Geol. Soc. of Dublin*, VI. pp. 212—13. Du Noyer, & Willson, *Explanations to accompany Sheet* 184 *of the Geological Survey of Ireland*, p. 37. *Ante*, pp. 616—19, *Table XXI.*

† Lloyd, *Trans. Royal Irish Academy*, XXII. pp. 418,—23. *Ante*, p. 741.

tions were made, at various times, in different parts of them, with the undermentioned results.

Localities.	Depth below the surface. fms.	Temperature. 1840. October.	Temperature. 1841. June.
North, Engine, or *Ardtully, lode.*			
Water, a small stream oozing out of slate in the N. side *(wall)* (a)..	17·	50·6°	°
" , " " *lode* W. (b) ..	"	51·25	
" , a large stream out of slate (a)	20·	..	53·
" , " " *lode* (b)	22·	51·25	
" , " " " (b)	27·	..	55·
" , pumped to the surface.... in 1840 from..	22·	51·	
" , " " .... " 1841 " ..	27·	..	53·

ENGLAND.

CORNWALL.

THE CARADON DISTRICT,—

which rises from about 600 to 1,200* feet above the sea,—comprehends rocks of granite,† slate,‡ *elvan*,§

* Mac Lauchlan, (De la Beche's), *Report on the Geology of Cornwall, Devon, and West Somerset*, pp. 14, 18. *Ante*, p. 696.

† Boase, *Cornwall Geol. Trans.*, IV. pp. 170, 209—10. De la Beche, *Report on the Geology of Cornwall*, &c., pp. 157,—9. Whitley, *Reports of the Royal Institution of Cornwall*, XXXII. p. 31. Thomas (Charles), *Remarks on the Geology of Cornwall and Devon*, p. 15. Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, p. 67. Holl, *Quarterly Journal of the Geol. Society*, XXIV. p. 440. *Western Daily Mercury*, No. 2,463 (28th May, 1868), p. 2. *Ante*, pp. 656—60,—62—66.

‡ Rogers, *Cornwall Geol. Trans.* II. pp. 218—20. Boase, *Ibid*, IV. p. 208. De la Beche, *Report on the Geology of Cornwall*, &c., p. 79. Giles, *Cornwall Geol. Trans*, VII. pp. 155—6,—8. Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, p. 67. Holl, *Quarterly Journal of the Geol. Society*, XXIV. p. 444. *Ante*, pp. 656—60,—67—70.

§ Boase, *Cornwall Geol. Trans.*, IV. pp. 209—10. De la Beche, *Report on the Geology of Cornwall*, &c., pp. 159,—83,—85. Giles, *Cornwall Geol. Trans.*, VII.

and greenstone.* The *lodes* wrought at *South Caradon*, *West Caradon*, and *Gonamena*, on the S., traverse granite and *elvan*, abound in fluor, and yield only copper and copper-ore; † whilst those opened at *Marke Valley* and the *Phœnix* mines, towards the N., intersect slate, granite, and *elvan*, contain no fluor, but afford the ores of both copper and tin,‡ *Cross-veins* occur in several parts of the district; § but neither of them has been traced throughout its entire breadth.

The mean temperature of Plymouth, some sixteen miles S.E., deduced from 43,824 horary observations, made at about 60 feet above the sea, during five years, was 52°·081.‖

At different depths, in various parts of the Caradon district, the undermentioned temperatures were observed:—

Localities.	Rocks.	Depth below the surface. fms.	Relation to the sea-level. fms. ¶	Temp.
Cheesewring Hotel.				
Water, in a deep well, full to within 4 fms. of the surface (25th July, 1867)	Granite .	4·	180· A	50°·9

pp. 158, 201. Webb & Geach, *History and Progress of Mining*, &c., pp. 33,—6. Holl, *Quarterly Journal of the Geol. Society*, XXIV. pp. 415,—41,—45. *Ante*, pp. 660,—1.

* Rogers, *Cornwall Geol. Trans.*, II. pp. 218—21. Boase, *Ibid*, IV. pp. 207—9. De la Beche, *Report on the Geology of Cornwall*, &c., p. 79. Giles, *Cornwall Geol. Trans.*, VII. pp. 156,—8. Holl, *Quarterly Journal of the Geol. Society*, XXIV. pp. 421,—23,—44. *Ante*, pp. 655,—71.

† Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, pp. 31,—6, 51—3. *Ante*, pp. 678—80, *Tables XXIII., XXIV.*

‡ Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, pp. 24—31. *Ante*, pp. 676—80. *Tables XXV.—XXVI.*

§ Whitley, *Geological Map of the Caradon Mining District.* Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, pp. 25, 31,—3,—5, 52. *Ante*, pp. 681—5; *Tables XXIII.—IV.,—VI.*

‖ Harris, *Reports of the British Association*, VII. pp. 24—5, *Pl. X.*

¶ Approximate.

Localities.	Rocks	Depth below the surface. fms.	Relation to the sea-level. fms.	Temp.
Gonamena.				
Water in the *adit*, a very large stream out of the (*Country*) rock and *lode*; taken for household use in the neighbourhood, as it flows out at the surface	Granite.	20·	130· A	51°·4
South Caradon.				
Water, a very large stream out of the *Little Cross-course*..	Granite.	44·	96· A	51·4
" , pumped to the *adit* (14 fms. below the surface) .... from..	"	128·	12· A	61·5
The Phœnix Mines.				
Water, oozing out of the (*Country*) rock and *lode* at the bottom of the mine.	Granite.	146·	14· A	67·
" , pumped to the *adit* (26 fms. below the surface) ..... from..	"	"	"	52·6
Marke Valley.				
Water, a small stream out of *Sarum lode* (*back* of *level*)	Slate ..	106·	14· A	60·5
" , " (*bottom* ")	"	"	"	62·5
" , " (*end* " E.)	"	"	"	70·
" , a large stream out of *Marke lode*, W.	Granite.	"	"	68·3
" , pumped to the *adit* (26 fms. below the surface..... from..	..	"	"	69·8

THE MENHENIOT DISTRICT,

rather more than three hundred feet above the sea,* comprehends an extensive area of—more or less calcareous †—clay-slate,‡ which contains, at intervals,

* "The Menheniot station on the Cornwall Railway is 261·5 feet above the sea-level."—J. D. SHERIFF, Esq., C.E., Engineer of the Cornwall and West Cornwall Railways, MS.

† Boase, *Cornwall Geol. Trans.*, IV. p. 212.

‡ Henwood, *Reports of the Royal Institution of Cornwall*, XXXIII. (1851),

numerous small cavities filled with earthy ferruginous matter (? of organic origin *); in some places the slate encloses, but in other it is interlaid by rocks of felspar and hornblende,† occasionally of schistose, though usually of massive, structure.‡ The only *lode* yet discovered in the neighbourhood has afforded, and—at more than two hundred and fifty fathoms deep—still continues to afford, great quantities of argentiferous galena § and smaller proportions of other, less valuable, ores. Barren *(flucans)* veins of clay ‖ *(heave)* displace the *lode* in several parts of its range.

During the years 1833—1837 the mean temperature at Plymouth, some eleven miles S.E., was 52°·081.¶

Streams derived from various parts of the slate series have—at different times—shown the temperatures hereafter mentioned.

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p. 39. Sedgwick, *Quarterly Journal of the Geol. Soc.*, VIII. pp. 5, 17, 146. Giles, *Cornwall Geol. Trans.*, VII. p. 201. Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, p. 38. Salmon, *Mining and Smelting Magazine*, II. p. 211. Holl, *Quarterly Journal of the Geol. Society*, XXIV. p. 423. *Ante*, pp. 700—4.

* *Ante*, p. 700.

† Rogers, *Cornwall Geol. Trans.*, II. p. 221. Boase, *Ibid*, IV. p. 211. Henwood, *Reports of the Royal Institution of Cornwall*, XXXIII. p. 39. Giles, *Cornwall Geol. Trans.*, VII. p. 201. *Ante*, pp. 701—2.

‡ *Ante*, pp. 701—2.

§ Henwood, *Reports of the Royal Institution of Cornwall*, XXXIII. p. 40. Giles, *Cornwall Geol. Trans.*, VII. p. 203. Salmon, *Mining and Smelting Magazine*, II. p. 218. Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, pp. 26, 36. *Ante*, pp. 703—14; *Tables XXVII.—VIII.*

‖ Henwood *Reports of the Royal Institution of Cornwall*, XXXIII. pp. 40,—2. Webb & Geach, *History and Progress of Mining in the Caradon and Liskeard District*, p. 37.

¶ Harris, *Reports of the British Association*, VII. pp. 24—5, *Pl. X.* *Ante*, p. 745.

Localities		Depth below the surface. fms.	Relation to the sea-level. fms.*	Temp.
Liskeard.†				°
Water in a closed well at the London Inn....	.. 1851, Sept 16th.	0·6	73· A	53·2
" Dean's (closed) well	.. 1867, July 30th.	1·	71· A	54·
Menheniot.				
Water in an open well, midway between the Church and *Wheal Mary Ann*	1867, July 29th.	Surface.	65· A	54·7
South Wheal Trelawny.				
Water, a small stream out of veins		53·	about sea-level.	56·5
" pumped to the *adit* (13 fms. deep) ..	from	73·	20· B	56·5
Wheal Mary Ann.‡				
Water, a large stream out of *lode*, bottom of the mine ..	1851, Sept. 9th.	98·	48· B	67·5
" pumped to the surface ..	1867, July 29th from..	280·	230· B	64·5
Wheal Trelawny.§				
Water, a moderate stream out of the *lode* N.	1851, Sept. 8th.	68·	18· B	60·
" , a small stream "	" ..	95·	45· B	65·
" , a large stream out of the *lode* S.	" ..	105·	55· B	65·
" pumped to the surface ..	1867, July 29th from..	210·	160· B	65·3

THE LANRRATH AND SAINT PINNOCK DISTRICT

rises from 150 ‖ to, perhaps, 200 feet above the sea;

* Approximate.

† "The centre of the Parade at Liskeard is 425 feet above the sea." ALLEN, *History of Liskeard*, p. 454.

‡ Within these sixteen years *Wheal Mary Ann* has been deepened 182 fms

§ " " *Wheal Trelawny* " 105 " .

‖ "Moorswater, the head of the Liskeard and Looe Canal, is 150 feet above the sea."—ALLEN, *History of Liskeard*, p. 454.

and consists of calcareous slates, which sometimes contain organic remains.* The *lode* at *Herod's-foot* —the only one yet wrought to advantage—has yielded, and still yields, an abundance of argentiferous galena, and *bunches* of copper-pyrites, beside smaller quantities of several other ores.† The *lode* is *(heaved)* displaced by a cross- *(flucan)* vein; which consists mostly of schistose matter, but is, at intervals, thinly sprinkled with ore.‡

In climate, *Herod's-foot* can scarcely differ much from Plymouth, Caradon, and Menheniot.§

The undermentioned temperatures have been observed in different parts of the district:—

Localities.		Depth below the surface. fms.	Relation to the sea-level. fms.‖	Temp.
Duloe.				°
Water in an open well at Benoke ..	1851, Sept. 18th	Surface	33· A	55·4
Saint Keyne.				
Water in an open well¶	1851, Sept. 18th	Surface	25· A	55·4
Herod's-foot.				
Water, a large stream out of the *lode* S.	1851, Sept 15th	137·	110· B	67·5
„ pumped to the surface....	1867, July 27th from..	160·	135· B	61·

* Giles, *Cornwall Geol. Trans.*, VII. pp. 97—9, 171. Peach, *Ibid*, p. 104. Sedgwick, *Quarterly Journal of the Geol. Society*, VIII. pp. 5, 17. Holl, *Ibid*, XXIV. p. 423. *Ante*, p. 700.

† Giles, *Cornwall Geol. Trans.*, VII. pp. 201—3. Salmon, *Mining and Smelting Magazine*, II. pp. 211—17. Webb & Geach, *History and Progress of Mining in the Caradon & Liskeard District*, pp. 16—18. *Ante*, pp. 705—15; *Table XXIX.*

‡ *Ante*, pp. 715—18, *Table XXIX.*

§ Harris, *Reports of the British Association*, VII. pp. 24—5. *Ante*, pp. 745,—7.

‖ Approximate.

¶ Carew, *Survey of Cornwall* (1602) f. 130. Norden, *Speculi Britannie Pars.* p. 86. Southey, *Poetical Works.* p. 656. Blight, *Ancient Crosses and other Antiquities in the East of Cornwall*, pp. 90—2.

SHROPSHIRE.

At *Eardiston*, some five miles S.E. of Oswestry, the New Red Sandstone and a band, varying in width from a few inches to perhaps five feet, by which it is intersected, both consist, in great measure, of granular quartz; but, whilst the former is tinged, more or less deeply, by various proportions of ferruginous matter, the latter contains, at intervals, great quantities of earthy brown iron-ore, sometimes largely mixed with the green carbonate of copper, and occasionally thinly sprinkled with grey copper-ore.* At a depth of sixteen fathoms, however, the iron-ore is replaced by blue clay, when all trace of copper-ore suddenly disappears.

A narrow ferruginous *cross-vein* intersects the whole formation; but occasions no *(heave)* displacement.

At Whittington, about five miles N.N.W. of *Eardiston*, the temperature, — between March 1842 and February 1843,— ranged from 11° to 81°, and averaged about 49°·7.†

* Murchison. *Silurian System*, pp. 39, 298. *Ante*, pp. 515—16.

† At Whittington, within five miles of *Eardiston*, the extreme and mean temperatures from March 1842 to February 1843, were—

Months.	9 A.M. Max.	9 A.M. Min.	9 A.M. Av.	3 P.M. Max.	3 P.M. Min.	3 P.M. Av.	9 P.M. Max.	9 P.M. Min.	9 P.M. Av.	Register Thermometers. Max.	Register Thermometers. Min.	Register Thermometers. Av.
	°	°	°	°	°	°	°	°	°	°	°	°
1842. March ..	50·3	35·7	44·	55·	40·7	48·1	49·	36·	41·	61·	28·	43·1
April ..	55·	37·	45·8	65·3	43·	53·8	54·	35·	42·3	67·	24·	44·2
May	60·5	45·	54·2	68·	52·	59·8	54·	39·3	48·2	69·	33·	52·1
June ..	69·3	55·	62·	79·2	59·7	68·	64·	47·	55·9	81·	34·	59·8
July	69·	54·2	61·4	74·	55·3	66·1	61·	49·	54·9	75·	41·	59·1
Aug. ..	70·5	55·2	64·4	80·5	55·5	66·4	63·	45·	58·6	81·	42·	62·3
Sept. ..	68·	50·	57·3	70·2	51·7	61·4	63·	42·5	56·6	74·	34·	55·4
Oct.	55·	32·	45·7	57·5	40·	49·7	49·	32·2	41·8	59·	24·	44·5
Nov. ..	48·5	34·	40·7	50·5	38·	43·4	47·3	30·	37·8	52·	28·	41·
Dec.	55·2	31·	44·2	56·2	37·5	47·3	55·3	31·5	44·9	59·	27·	45·2
1843. Jan. ..	52·	22·5	38·5	53·	32·2	41·8	51·	27·	38·8	56·	15·	39·1
Feb.	42·3	19·	34·4	47·5	28·	36·8	46·5	18·	33·7	51·	11·	34·4
Extremes	70·5	19·	..	80·5	28·	..	64·	18·	..	81·	11·	
Means	..	..	49·4	..	..	53·5	..	..	46·2	..	..	48·35

49·7

THE REVEREND C. A. A. LLOYD, MS.

At *Eardiston* on the 17th—18th of November, 1842—

water at the surface..... was frozen;

„ issuing from the metalliferous band at 15 fms. deep, had a temperature of } 54°:

„ pumped to the surface ..... from 16 „ „ , „ 50°;

It may, perhaps, be desirable, to place the facts, already described, in such various points of view, as may disclose their respective peculiarities.

The mean depths of the mines in *each district*;—

„ „ temperatures „ „ ;—

„ „ *ratios* of increase in temperature, expressed in fathoms of descent requisite to an elevation of one degree; * .... } „ „ ;—

„ „ annual temperatures at the surface.... } „ „ ;—

are set forth in the following columns:—

Countries.	Provinces & Districts.	Underground.			Surface.
		Mean depth. fms.	Mean temp.	Mean ratios. fms.	Mean annual temp.
CHILI	Chañarcillo	155	69°·2	21·6	64°· †
BRAZIL	Minas Geräes	53	67·9	26·2	60·49 ‡
UNITED STATES ..	Virginia.....	15	56·8	§	55· †

For the foregoing extracts, from a *Meteorological Register* which extends from March 1842 to July 1851, the writer is indebted to the Reverend Albany Rossendale Lloyd of Hengoed and George James Symons, Esq., F.M.S., Editor of "*British Rainfall.*"

* Henwood, *Cornwall Geol. Trans.*, v. p. 404.

† Keith Johnston, *Atlas of General Phænomena, Pl. XVIII. Ante*, p. 724.

‡ *Ante*, pp. 726—8,—9,—32. *Tables XXX.—XXXI.*

§ One observation only.

Countries.	Provinces & Districts.	Underground. Mean depth. fms.	Mean temp.	Mean ratios. fms.	Surface. Mean annual temp.
CHANNEL ISLANDS	Sark & Herm	37	55°·5	10·	51°·6 *
IRELAND.....	Wicklow, Waterford, Cork, & Kerry ..	57	53·4	14·1	50·3 † 52·3 †
ENGLAND	Cornwall	92	62·5	5·8 ‡	52·08 §
	Shropshire	15	54·	‖	49·7 ¶

Other details appear in *Table XXXII.*

The mean—depths,—temperatures,—and ratios in which the temperatures increase with the depths, in

* Ansted, *Channel Islands*, p. 140. *Ante*, p. 735.

† Lloyd, *Trans. Royal Irish Academy*, XXII. pp. 416,—22,—3,—4. *Ante*, pp. 738,—9,—41,—3. R. J. Greer, Esq., MS. *Ante*, p. 739.

‡ In the principal mining districts of Cornwall and Devon four hundred and fifteen observations afforded the undermentioned results:—

Districts.	Mean depth. fms.	Mean temp.	Mean ratios.	Districts.	Mean depth. fms.	Mean temp.	Mean ratios.
Saint Just	95	57°·84	14·3	Camborne, &c.	98	62°·13	10·6
Saint Ives	129	63·56	11·2	Redruth, &c. .	132	71·37	5·8
Marazion	76	63·87	7·7	Saint Agnes ..	99	65·91	8·4
Gwinear, &c. ..	101	63·4	7·4	Saint Austell ..	136	70·62	5·
Helston	134	66·66	8·8	Tavistock, &c..	72	59·07	8·9

Mean depths..... 112 fms.;—
" temperatures .... 66°88;—
" ratios ..... 6·8 fms.
HENWOOD, *Cornwall Geol. Trans.*, V. pp. 402,—6.

§ Harris, *Reports of the British Association*, VII. pp. 24,—5. *Ante*, pp. 745—7.

‖ One observation only.

¶ The Reverend C. A. A. Lloyd, of Whittington near Oswestry, MS. *Ante*, p. 750.

the *different rocks* of the several districts already mentioned, appear in the following pages:—

Rocks.	Mean depth. fms.	Mean temp.	Mean ratios.
New Red Sandstone*	15	54°.	One observation only.

* "New Red Sandstone [is] very much affected in its conductivity by being saturated with moisture.

Two blocks,—of which the second was the harder,—possessed the undermentioned powers of conduction when in different conditions;—

	1.	2.
Dry	25	49
Saturated with moisture....	60	62 65

HOPKINS, *Phil. Trans.*, CXLVII. pp. 808,—18,—19.

At the mine of *Monk-Wearmouth*—which was sunk,—
264· fms. beneath the surface,
249·5 „ „ sea,
to the coal-seams which underlay the magnesian limestone of Durham—
the mean temperature at the surface ..... was .. 47°·6
„ „ the depth of 264 fms. „ .. 72°.6
If, therefore, the depth of the invariable plane be taken at „ 16·6 „, we have an increase of temperature equal to one degree for 9·9 fms. of descent.

PHILLIPS, *London and Edinburgh Phil. Mag.*, v. pp. 446—51 (Abridged).

The coal-mine of *Torcy* (Department of Saône et Loire)—
was opened at ..... 169·3 fms. above the sea;—and
„ sunk ..... 155·9 „ below „ ;—
the total depth thus being ..... 325·2 „ „ the surface.
The annual mean of the climate ..... was 48°·5;
„ temperature maintained at 303 fms. deep, in an abandoned part of the mine ..... „ 81°.

The works of Mouillelonge, some two miles distant,—
were commenced ..... at 175·3 fms. above the sea;
and—having pierced the New Red Sandstone—entered the Coal-measures ..... „ 20·7 „ below „ ;
they were continued, however..... 250· „ deeper;—
reaching eventually a depth of 207·7 fms. below the sea, or..... 446· „ beneath the surface,
where the temperature ..... was 100°·9.

Now the difference
between the annual mean at *Torcy*, and the temperature at 303 fms. in the mine ..... was 32°·5 (1);—
„ „ „ 446 „ in *Mouillelonge* „ 52°·4 (2);—
„ 333 fms. at *Torcy* „ „ „ „ „ „ 19°·9 (3).

Rocks.	Mean depth. fms.	Mean temp.	Mean ratios.
Limestones alternating with Felspathic and Hornblendic rocks	155	69°·2	21·6

The ratio in which the temperature increases with the depth was—
in the first case, one degree for 9·2 fms.;—
" second " " " 8·5 " ;—
" third " " " 7·2 " .
(WALFERDIN, *Comptes Rendus*). SMYTH (Annual Address), *Quarterly Journal of the Geol. Soc.*, XXIV. pp. lxxix.—lxxx. (Abridged).

The *Duckinfield* colliery afforded rare opportunity for observing, in two shafts, the gradual increase of temperature with depth. Of the observations made by F. D. Ashley, Esq., the proprietor, a synopsis is presented in the following columns:—

First Shaft.					Second Shaft.				
Extremes.		Means.			Extremes.		Means.		
Depth. fms.	Temp.	Depth fms.	Temp.	Ratios.	Depth. fms.	Temp.	Depth. fms.	Temp.	Ratios.
2·8	51°·								
		59·1	54°·4		83·7	58°·	95·8	58°·2	
115·5	57·7			18·5	119·7	59·			
117·3	58·	127·6	58·1						34·
146·5	59·5			12·9	127·	58·2	136·6	59·4	
150·	59·9	161·2	60·7		147·5	60·			
179·	62·5			9·3	154·	60·			14·4
186·5	64·	203·	65·2		179·	62·	164·	61·3	
216·5	66·5			15·4	191·2	63·5			15·
223·	67·	232·3	67·1		218·2	65·5	204·5	64·	
241·7	67·2			13·6	227·7	66·			11·9
243·5	67·7	255·4	68·8		233·5	66·5	230·6	66·2	
266·5	69·7			9·6					
269·5	69·9	281·4	71·5						
294·5	71·5			46·5					
298·5	72·2	309·3	72·1						
322·7	72·2			15·3					
325·5	72·5	338·3	74·						
358·5	75·								

Rocks.	Mean depth. fms.	Mean temp.	Mean ratios.
Felspathic and Hornblendic Rocks	37	55°·5	10·

It appears therefore, that the rocks in these neighbouring shafts maintain different temperatures at corresponding depths; and that at various parts—of even the same shaft—the temperatures increase, with the depths, in widely different ratios.

At the first shaft, indeed,

At the second shaft— 58 observations were made, and in 17 of them } the temperatures at the lower exceeded those at the upper stations;
18 „ „ , „ 2 „

of these differences, however, only one amounted to one degree and a quarter, whilst most of the others were much smaller.

Nevertheless, that the temperature increases at an average of one degree for a descent of

14·8 fathoms in the first shaft, and of
16·8 „ „ second „ ,

is indisputable.

FAIRBAIRN, *Report of the British Association*, 1861, Part II. pp. 53—6. (Paraphrased and abridged.)

The Rose Bridge collieries, at Ince near Wigan, have afforded opportunity for the undermentioned observations :—

Depth, fms.	Temperature.	Ratios.	Depth, fms.	Temperature.	Ratios.
80·5	64°·5		339·5	87°·	
100·	66·	13·	367·	88·5	18·3
279·	78·	14·9	372·5	89·	11·
302·5	80·	11·7	380·5	90·5	5·3
315·	83·	4·1	387·5	91·5	7·
331·5	85·	8·2	391·5	92·	8·
335·5	86·	4·	400·	93·	8·5
339·5	87·	4·	403·	93·5	6·

From 80·5 to 403 fathoms therefore the increase of temperature averages one degree for 11·1 fathoms.

For this interesting record the writer is indebted to
JOHN ARTHUR PHILLIPS, ESQ.

In the Coal-mines of Virginia, which are believed to be of the Oolitic period (LYELL, *Quarterly Journal of the Geol. Soc.*, III. p. 261), Professor W. B. Rogers observed that

from 66 to 100 fms. deep the increase of temperature amounted to } 4°·5 or at the rate of 1 degree in 7·5 fms.;
„ 100 „ 130 „ „ „ 2·5 „ „ 12· „ ;
„ 66 „ 130 „ „ „ 7· „ „ 9·1 „ .

D'ARCHIAC, *Histoire des Progrès de la Géologie*, I. p. 71.

Rocks.	Mean depth. fms.	Mean temp.	Mean ratios.
Clay-slate*	70	61°·8	11·3
Jacotinga †	40	67·3	—
Talcose, micaceous, and chloritic slates	18	62·9	‡
Granite*	79	59·5	5·8

The mean — depths,—temperatures,—and rates at which the temperatures increase with the depths — of the mines which yield *different metals and ores (Table XXXIV.)*, are—

Metals and Ores.	Mean depth. fms.	Mean temp.	Mean ratios.
Gold	51·	67°·5	23·
Silver	155·	69·2	21·5
Lead	72·	60·7	8·4
Copper §	43·	53·7	15·9

* From one hundred and thirty-four observations, in the mines of Cornwall, between 1830 and 1837, it appeared that the slate was about 3°·9 warmer than the granite at the same depth. But four hundred and fifteen observations made in Cornwall and Devon from 1830 to 1843 showed—
that at a mean depth of 116 fms. the temperatures of the slate averaged 68°·89;
" 94 " " granite " 60°·35.
HENWOOD, *Reports of the British Association*, VI. (1837) Part II. p. 37; *Cornwall Geol. Trans.*, V. p. 403.

† The mine of *Agoa Quente*—notwithstanding its depth hardly exceeded thirty fathoms—discharged more than three hundred cubic feet of water per minute. Of this enormous stream—
at depths ranging from 4 to 15, and averaging 8·5, fms.—the temperature varied from 70°·2—86°·5 & averaged 78°·76,
" 18 " 29, " 26·3, " — " 77°·8—92°·5 " 87°·15;
an increase at the rate of one degree in (2·12) little more than two fathoms.

These temperatures so greatly exceed those observed, at corresponding depths, in any other mine, and the vertical range of observation is so small, that they have not been used in deducing the foregoing means.

‡ Two observations only.

§ "Fox observed [that] * * * tin veins usually shewed themselves colder

Metals and Ores.	Mean depth. fms.	Mean temp.	Mean ratios.
Copper and Tin* ..	114	65°·7	—†

But whilst *Morro Velho* and *Gongo Soco* have been rich in gold, by far the larger part of the auriferous deposits have consisted of iron-pyrites in one, and of specular iron-ore in the other. Moreover, in the *lodes* which yield copper-ore,—whether mixed or unmixed with the oxide of tin,—iron-pyrites always abounds.

Between the temperatures and ratios observed, at various depths, in mines which have afforded *similar metals and ores in rocks of different character*, as well as between the temperatures and ratios noticed in such other mines as have yielded *different metals and ores in rocks of like nature*, the following comparisons have been made *(Table XXXV.)*:—

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than those which yielded copper."—*Annales et de Chimie et de Physique*, XVI. p. 80; *Edinburgh New Phil. Journal*, XXIV. p. 140.

"The tin mines of the *Sauberg* at *Ehrenfriedersdorf* also show a remarkably low temperature; indeed it is a prevailing opinion that stanniferous mountains are colder than others."—REICH, *Beobachtungen ueber die Temperatur des Gesteins in verschiedenen Tiefen in den Gruben des Sachsischen Erzgebirges*, pp. 87, 107. BISCHOFF, *Edinburgh New Phil. Journal*, XXIV. p. 140.

The following are the mean depths at which observations were made, and the mean temperatures observed in the *lodes* affording different ores in the principal mining districts of Cornwall and Devon.

Lodes.	Mean depth, fms.	Mean temperature.
Copper	140	72°·39
Copper and Tin	74	61·45
Tin	92	60·67

HENWOOD, *Cornwall Geol. Trans.*, V. p. 404.

* *Ante*, p. 756, Note §.

†Means of five observations, but all at the same horizon.

Rocks.	Metals and Ores.								
	Gold.			Lead.			Copper.		
	Mean depth fms.	Mean temp.	Mean ratios.	Mean depth fms.	Mean temp.	Mean ratios.	Mean depth fms.	Mean temp.	Mean ratios.
New Red Sandstone	..	..	..	..	..	..	15	54°·	*
Felspathic & Hornblendic rocks ..	..	..	..	48	56°·8	13·5	30	54·7	9·4
Clay-slate	67	68°·4	25·2	93	63·6	10·7	57	53·4	14·1
Jacotinga	42	67·3							
Talcose and Micaceous slate	18	62·9	†						
Granite	..	..	..	..	..	..	32	51·4	†
Means	51	67°·8	23·	72	60°·7	8·4	43	53°·7	15·9

Amongst the mines described in foregoing pages, those which have yielded silver and gold occupy high ranges of mountains, within the tropics; whilst such as have afforded the ores of other metals have been wrought in less elevated parts of temperate regions. Between the mean-depths,-temperatures,-and ratios in which the temperatures increase with the depths, in works thus differently situated, a comparison is offered —as well in *Tables XXXII.* and *XXXVI.* as—in the following columns:—

Metals and Ores.	Comparative elevation of surfaces, fms.	Mean depth. fms.	Mean temp.	Mean ratios.
Gold and Silver	More than 200	65	67°·7	30· ‡
Lead, Copper, and Tin ..	Less than 200	61	57·	8·9
Means.....	..	62	62·3	16·3

* A single observation.

† The only observations have been made at the same horizon.

‡ In the clay-slate of *Morro Velho*, temperature increases with depth much

As far as these observations extend, therefore, it appears that at considerable altitudes within the tropics, the temperature is higher than at corresponding levels below the surface at smaller elevations in temperate regions; but that the ratio at which it increases with the depth is much less rapid in the former than in the latter.

The mean—depths,—temperatures,—and ratios at which the temperatures increase with the depths, of the mines before mentioned, irrespective of their geographical positions, altitudes, rocks, metals and ores,—are the following:—

Extreme depth, fms.	Mean depth, fms.	Mean temp.*	Mean ratios.*
Surface to 50 ..	28	61°	
50 „ 100 ..	65	60·5	21·4
100 „ 150 ..	122	65·4	
150 „ 200 ..	155	72·	5·
200 and beyond .	227	73·2	60·
Means	62	62·3	16·3

less rapidly than it has been found to increase in the similar rocks of Cornwall. HERWOOD, *Proceedings of the Royal Geol. Soc. of Cornwall*, 24th Oct. 1865.

At *Morro Velho* in Brazil the rate at which the temperature increases is but one degree for (33·3 fathoms) 200 feet.—SMYTH, *Quarterly Journal of the Geol. Soc.*, XXIV. (1868) p. lxxxvi.; *Ante*, p. 727.

* One hundred and thirty-four observations in the mines of Cornwall and Devon afforded—between 1830 and 1837—the following results:—

But at great altitudes in tropical regions—where the temperatures are above, whilst the ratio is below, the average,—and at smaller elevations in temperate climates,—where the ratios exceed, whilst the temperatures fall short of it,—observations have not been made

	ROCKS.					
	SLATE.			GRANITE.		
Extreme depth. fms.	Mean depth. fms.	Mean temp.	Ratios. *a*	Mean depth. fms.	Mean temp.	Ratios. *a*
Surface to 50	35	57°·	8·8	31	51°·6	11·4
50 „ 100	73	61·3	8·1	79	55·8	5·6
100 „ 150	127	68·	4·3	133	65·5	6·6
150 „ 200	170	78·	6·1	—	—	
200 and beyond..	221	85·6		237	81·3	
Means	.....	.....	6·5	.....	.....	6·9

HENWOOD, *Thomson's Records of General Science*, IV. (1836), p. 198; *Reports of the British Association*, VI. (1837), Part ii. p. 36.

"By burying the bulbs of different thermometers at various depths below the deepest excavations of mines" the undermentioned results were obtained:—

Mines.	Depth below surface. fms.	Temperatures.	Ratios from surface.
Levant	230	80°·	7·6
Tresavean	262	82·	8·
Consolidated Mines	290	85·3	8·3

FOX, *Report of the British Association*, VI. (1837, Part I.), pp. 134—7. (Abridged.)

"Upon the whole, I believe that * * * the ratio in which the temperature augments in descending is greater in shallow than in deep mines."

FOX, *London and Edinburgh Phil. Mag.*, XI. (1837), p. 523.

At a mean elevation of about 240 feet above the sea, the ground, at a depth of three feet, maintained, throughout the year, an average temperature of 49°·86.

One hundred and seventy-seven observations, in different parts, but not the

a These columns are now added.

in the same proportions at different depths. Thus,—

Extreme depth, fms.	Observations in elevated tropical regions.	Observations at moderate altitudes in temperate climates.
Surface to 50	24	17
50 „ 100	5	12
100 „ 150	4	10
150 „ 200	2	—
200 and beyond..	2	—
Totals	37	39

deepest, of many mines in Cornwall and Devon, exhibit increments of temperature equal to 10° each at intervals of about 47, 79, and 125 fathoms of descent.

Whilst fifty-three experiments in the deepest levels or accessible parts of mines show the rock, water, and air to preserve in round numbers,—

a temperature of	60°	.... at	59 fms.	below the surface;		
„	70	.... „	132 „	„ ;		
and „	80	.... „	239 „	„ ;		
being an increase of	10	.... „	59 „	„ ;	or 1° in 6.	fms.
„	10	more „	73 „	.. deeper;	„ 7·3	„ ;
„	10	„ „	114 „	still deeper;	„ 10·7	„ .

Fox, *Reports of the British Association*, for 1840, pp. 310—16 (Abridged.)

The following columns show the respective ratios of increase in temperature expressed in fathoms of descent requisite to produce an elevation of one degree; deduced from four hundred and fifteen observations in the mines of Cornwall and Devon:—

Depth. fms.	Granite. fms.	Slate. fms.	Rocks. fms.	*Cross-courses.* fms.	*Lodes.* fms.	Tin-*lodes.* fms.	*Lodes* yielding both tin and copper ores. fms.	Copper-*lodes.* fms.	Means. fms.
Surface to 50	9·3	5·	5·8	8·2	6·	8·6	6·5	4·6	6·8
50 „ 100	9·1	7·1	8·1	6·	8·3	7·3	6·4	8·5	7·6
100 „ 150	8·3	8·3	6·7	11·	7·8	8·5	10·5	8·	8·7
150 „ 200	..	4·4	3·7	4·9	6·3	..	3·	4·5	4·5
200 & beyond	7·5	6·5	9·5	3·9	5·2	5·1	..	6·5	6·4
Means ..	8·5	6·2	6·7	6·8	6·7	7·3	6·6	6·4	6·8

HENWOOD, *Cornwall Geol. Trans.*, v. p. 406; (D'ARCHIAC), *Histoire des Progrès de la Géologie*, I. p. 69.

This preponderance of observation—
at less than 50 fathoms deep in elevated, tropical, regions;
from 50 to 150 „ „ in lower, temperate, countries;
and at all greater depths ... at great altitudes within the tropics,
accounts for the *apparently* higher temperature from the surface to fifty—than from fifty to one hundred—fathoms deep. Yet, whether unequal numbers of observations—in each of several countries so far apart,—at altitudes so various,—in rocks so different,—and in mines yielding so many metals and ores,—can afford results accurately representing the mean temperatures

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The temperatures observed in the *rocks* or *lodes* at the *deepest levels*, and ratios at which the temperatures increase with the depths, of mines in various parts of Cornwal, are—

Mines.	Ores.	Rocks.	Date of observations.	Depth. fms.	Temp.	Ratios.
Botallack	Copper & Tin.	Slate ..	1837	188	79°	6·5
Levant	Copper & Tin.	Slate ..	1853	255	87·	6·9
		Granite..	„	„	74·	10·6
		Slate	1857	„	85·	7·3
Dolcoath	Copper & Tin.	Granite..	1822	230	75·5	9·
			1857	272	73·	11·8
	(another *lode*)	.....	„	„	79·5	9·2
Tresavean	Copper	Granite..	1837	262	82·5	8·1
			1853	352	90·5	8·6
United Mines ..	Copper	Slate ..	1853	275	94·	6·3
Par Consols	Tin	Slate ..	1837	128	74·	5·7
	Copper		1837	208	84·	6·1

In the *United Mines*, at 255 fms. deep, } the temperature of the hot spring was } 116° & the ratio of increase 1° in 3·9 fms.;
„ in another *level*, „ ..... „ 93° „ „ 6·7 „ .

FOX, *Reports of the British Assoc.* for 1857 (Abridged and Paraphrased).

"The *North* or *Hot-Lode* of the *Clifford Mines*, formerly known as that of the

and ratios on any one vertical line, may, perhaps, be open to question.

The composition and structure peculiar to different strata afford greater or less facility for the ascent of water and vapour; which, co-operating with the conducting power proper, in various degrees, to all rocks, —aid as well in transferring towards the surface of the earth some portion of the heat maintained within it, as in determining to each formation its due distribution of temperature. Occasionally, however, this normal equilibrium is disturbed by the miner;* through

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United Mines, is one of a group of east and west [copper-] veins which are encased in the clay-slate or *killas*, on the east of the granite hill of Carn Marth. * * * The author found, in 1855, the chief spring welling upwards in a level 251·6 fathoms deep, with a temperature of 114°. * * * In [1864, however,] these parts of the workings had been laid dry by the extension of deeper galleries, and the point of egress of the springs was along the rich *lode*, advanced [much] farther eastward. * * * [In this part of the works] the principal body of the upward-flowing water was to be seen rising * * * on the north side of the magnificent *lode* of cellular, black-stained, cinder-like pyrites. The next *level* [at 270 fathoms below the surface] is advanced farther eastward by some 70 fathoms; the *lode* exhibited a good breadth of fine black-coated copper pyrites; and small feeders of water, issued mostly from the north, or *hanging-wall*, almost scalded the fingers holding the thermometer, which marked 122°. * * * At the bottom *level*, which is 275 fathoms deep; in its end the *lode* was narrow, and very impervious to water, but a little rill trickling from it showed a temperature of 121°. * * *

Between my last two visits * * * the point of issue of the hotter water had been deepened 30 fathoms, and the temperature was increased by 8°. This would give 1° for 3·75 fathoms. * * *

SMYTH, *Mining and Smelting Magazine*, VI. pp. 193—6; *Reports of the British Association*, for 1864, Part II. p. 70. (Abridged)

* "Numerous observations show that, whilst the conditions of the works on mines are unchanged, the temperatures at considerable depths are constant; but it seems not to have been ascertained whether the temperature of any spot —after other openings were extended beneath it—remained the same as it had been when it was the bottom of the mine. To invite enquiry on this subject, I venture to offer the following comparisons.

whose shafts and *(levels)* galleries, water and vapour circulate more freely than they had previously circulated through the cleavage-planes, joints, and crevices

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East Wheal Crofty (a copper-mine, wrought in felspathic and hornblendic rocks:—

	1838.		1840.	
	Depth, fms.	Temp.	Depth. fms.	Temp.
Longcloss, Engine-lode	85	63°·5	85	60°
„ , „	..	..	115	64·
Trevenson, Reeve's Lode	115	69·	115	62·
„ , „	..	..	135	70·75
Wheal Vor (a tin-mine, opened in clay-slate).	1838.		1859.[a]	
Main Lode, W.	..	..	210	74.5
„ , W.	..	..	222	75·
„ , E.	230	78·		
„ , E.	240	80·5 81·	240	74·
„ ; W.	..	..	251	80·
„ , W.	..	..		86·
„ , E.	..	..	311	82·5
„ , E., bottom of the *level*	..	..		90·25
„ , ...	..	..	321	91·
Water discharged by pumps at the *Adit*, from ..	240	69·	321	75·

Thus, at *East Wheal Crofty*,
on the *Longcloss Engine-lode*, the temperature
at the bottom..... was 63°·5 in 1838 when the works were 85 fms. deep;—
but it had fallen at the
same spot to .. 60· „ 1840 „ 30 „ deeper;—
yet at the bottom it had
risen to .... 64· „ „ „ 115 „ deep:

[a] These observations were made by the late Captain Francis Francis, with the same instruments which had been used by the writer in 1838.

in the rocks and *lodes;* as therefore, each successive extension of deeper works intercepts, in its turn, the ascent of warm currents, the temperature of the original bottom gradually declines.

That, here and there, portions of various rocks and vein-stones are cooler than those above them, seems too well authenticated to admit of question. Such, infrequent interpositions, however, are seldom of great vertical range, and there is reason to believe they have usually but small horizontal extent; moreover, between

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at *Reeve's Lode*, the temperature
at the bottom..... was 69·° in 1838 when the works were 115 fms. deep;—
but it had, at the same
spot declined to .. 62· „ 1840 „ 20 „ deeper:—
yet at the bottom it had
risen to..... 70·75 „ „ „ 135 „ deep.

At *Wheal Vor*,
the temperature on the *Main Lode*
at the bottom..... was 80°·5 in 1838 when the mine was 240 fms. deep;—
but it had at the same spot
fallen to .... 74·[a] „ 1859 „ 81 „ deeper;—
nevertheless at the bottom
it had advanced to .. 91·[a] „ „ „ 321 „ deep.

HENWOOD, *Cornwall Geol. Trans.*, v. (1843), p. 395; *Reports of the Royal Institution of Cornwall*, XLI. (1859), pp. 21—3; *Annales des Mines*, 5me Série, XVI. pp. 571—3.

At *Wheal Vor*, on the 30th September 1858, the mid-day temperature
at the surface was .... 67°;
but at the bottom, 311 fms. deep, the air and the water issuing from
the rock were both at .... 80°.

SMYTH (Annual Address), *Quarterly Journal of the Geol. Society*, XXIV. p. lxxxv. (Abridged.)

"On comparing the results obtained in Dolcoath in 1821—2 and 1827, it appears that the temperature was increased only 4° in one level with an increased depth of 42 fathoms, giving a ratio between the stations of 1° increase in 10·5 fathoms; and in another level the temperature was actually 2° to 2°·5 less than in 1822, although 42 fathoms deeper than the mine was then."

FOX, *Report of the British Association*, for 1857, Part I. p. 100.

[a] *Ante*, p. 764, Sub-note.

their temperatures and the temperatures of the warmer rocks above and below them, the differences rarely exceed two degrees, and usually they are much smaller. Whether this state of things is a natural one,—or whether—in fact—it may have been brought about by the shafts, *levels*, and other openings in which it has been observed,—is beyond the scope of this enquiry.

W. J. HENWOOD.

3, CLARENCE PLACE, PENZANCE,
1870, FEBRUARY 3RD.

On the changes of temperature which take place—at the same, and at different, times,—on the surface and at depths of three, six, and nine feet in the Canga, *at* Agoa Quente *in Brazil*

The following observations were made with a view to ascertaining the rate at which solar heat penetrates the earth.

The high granitic ridge of the Caraça,* situate in Long. 43° 10′ W., Lat 19° 50′ S., is, on the W.S.W. —separated by a deep and narrow glen from a parallel, but less elevated, range consisting of talco-micaceous slate,† and schistose iron-glance interlaminated with quartz *(Itabirite* ‡*)*, in which—at least—one conformable bed of auriferous *(Jacotinga* § *)* manganese, iron-glance, and talc has been extensively wrought. Considerable portions of the talco-micaceous slate, as well as of the *Itabirite* and *Jacotinga*, are overlaid by *(Canga* ‖ *)* breccia, containing sub-angular masses of the selfsame rocks and of quartz, usually cemented by compact brown iron-ore, but sometimes imbedded in

* *Ante*, pp. 174—6.

† *Ibid*, pp. 176, 220.

‡ *Ibid*, pp. 214,—21,—44,—8,—98.

§ *Ibid*, pp. 173, 214,—16,—19,—23,—7,—36,—46,—51,—86, 303, 729.

‖ *Ibid*, pp. 216,—17,—36,—45,—99, 319,—24.

"The ground rang under the hoof as if iron-plated; * * * . The appearance of the mineral reminded me of the laterite in Malabar and Western India, but here it is the richest hæmatite."

BURTON, *Explorations of the Highlands of the Brazil*, I. p. 315.

reddle. Particles of gold * and nests of native copper * occur in the *Canga*, but too rarely to need further remark.

Some four hundred fathoms N.W. of, and perhaps sixty fathoms above, the works at *Agoa Quente*,†—that is to say about three thousand six hundred feet above the sea—the surface is partially clothed with a stunted coppice of *(Lychnophora) Candeia*; ‡ and at this spot holes §—of two inches in diameter and respectively of three, six, and nine feet in depth—were sunk in the *Canga*.

Thermometers—adjusted to the Standard of the British Association, by Pastorelli of London—were placed at the bottoms of the holes; which were then carefully closed with long wooden plugs wrapped in

* *Ante*, p. 236.

† *Ibid*, pp. 224—42, 729—31.

‡ "Sur plusieurs pentes couvertes de pierres, je trouvai en grande abondance une espèce à petites feuilles du genre *Lychnophora* Mart. (Vulg. *candeia*), genre qui, dans les montagnes, caractérise les côtes pierreuses."—SAINT HILAIRE, *Voyage dans le district des Diamans et sur le littoral du Brésil*, I. p. 81.

Gardner, *Travels in the interior of Brazil*, p. 473.

§ "Mes observations sont comprises entre le 11e degré de latitude boréale et le 5e dégre de latitude australe. * * * J'ai toujours observé dans un endroit abrité, un rez-de chaussée, une cabane d'Indien, un simple hangar. * * * Dans le village de Zupia, mon thermomètre était placé au rez-de-chausée, dans un trou de 8 pouces pratiqué dans le, sol; ce trou avait un demi-pouce de diamètre. Le maison était couverte de fuilles de palmier. * * * Lorsque le thermomètre était en expérience, on bouchait l'orifice du trou avec un morceau de carton sur lequel on appliquait une grosse pierre.

"La température moyenne du village de Zupia avait été fixée à 21°·5 C. (70°·7 F.) par de nombreuses séries d'observations thermométriques faites en 1825, 1826 et 1829. Zupia ést élevé au-dessus de la mere de 1,225 mètres (4,019 feet).

"Je rapporterai maintenant la march du thermomètre au-dessous du-sol, telle que je l'ai observée dans différentes localités.—

cloth; and—except for a minute or two at each read-

	Zupia. 8 pouces sous terre.	Dans l'air.
1830.		
Août le 3 à 9 h. m.	21°·4 C. .. 70°·5 F.	21°·7 C. .. 71° F.
10	21·4 .. 70·5	22·2 .. 72·
11	21·5 .. 70·7	22·2 .. 72·
1	21·5 .. 70·7	23·8 .. 74·8
3	21·5 .. 70·7	22·8 .. 73·
le 9 à 8 h. m.	21·4 .. 70·5	20· .. 68·
midi.	21·4 .. 70·5	23·3 .. 74·
5	21·4 .. 70·5	22·2 .. 72·
le 10 à midi.	21·4 .. 70·5	23·3 .. 74·
4	21·4 .. 70·5	23·5 .. 74·3
le 11 à midi.	21·4 .. 70·5	22·5 .. 72·5
le 12 à 9 h. m.	21·3 .. 70·3	20·5 .. 68·9
midi.	21·3 .. 70·3	21·1 .. 70·
le 13 à 9 h. m.	21·3 .. 70·3	20·6 .. 69·1
3	21·5 .. 70·7	22·6 .. 72·7
4	21·3 .. 70·3	23·9 .. 75·
le 15 à midi.	21·3 .. 70·3	22·8 .. 73·
le 16 à midi.	21·3 .. 70·3	22·8 .. 73·
3	21·3 .. 70·3	22·3 .. 72·1
le 18 à midi.	21·3 .. 70·3	24·4 .. 75·9
La boule du thermomètre a été placée à un pied au dessous de la surface du sol.		
le 18 à 3 h. soir.	21°·5 C. .. 70°·7 F.	23°·4 C. .. 74°·1 F.
4	21·5 .. 70·7	22·3 .. 72·1
6	21·5 .. 70·7	21·7 .. 71·
9	21·5 .. 70·7	22·2 .. 72·
le 19 à 9 h.m.	21·5 .. 70·7	21·1 .. 70·
midi.	21·5 .. 70·7	21·7 .. 71·
2	21·5 .. 70·7	22·8 .. 73·
3	21·6 .. 70·9	22·2 .. 72·
6	21·6 .. 70·9	22·2 .. 72·
le 20 à 11 h.m.	21·5 .. 70·7	21·1 .. 70·
midi	21·5 .. 70·7	21·7 .. 71·
3	21·5 .. 70·7	22·2 .. 72·
le 21 à 3 h.s.	21·6 .. 70·9	
5	21·5 .. 70·7	
le 22 à 9 h.m.	21·5 .. 70·7	
3 h.s.	21·6 .. 70·9	

ing of the instruments—they were never reopened.

"Pendant les mois de septembre, octobre et novembre, le thermomètre a toujours indiqué 21°·5 C. (70°·7 F.)

Marmato.

"Le thermomètre a été placé à 1 pied dans la sol, dans une salle basse de la maison du surintendant des mines. La température moyenne de cette maison déduite d'une année d'observations est de 20°·5 C. (68°·9 F.). Elle est élevée au-dessus de l'Océan de 1,426 mètres (4,679 feet).

	Thermomètre sous terre.
1830.	
Septembre le 9 à 11 h.m.	20°·5 C. .. 68°·9 F.
1	20·5 .. 68·9
3	20·5 .. 68·9
le 10 à 8 h.m.	20·3 .. 68·5
11	20·3 .. 68·5
1	20·4 .. 68·7
2	20·5 .. 68·9
3	20·5 .. 68·9

Anserma Nuevo.

"Des observations faites par Caldas, dans voisinage d'Anserma, donnent à cette partie de la vallée du Cauca,"—élevée de 1,050 mètres—(3,545 feet) "une température moyenne de 23°·8 C. (74°·8 F.).

"Le thermomètre placé à 1 pied de profondeur dans le sol d'un rez-de-chausée.

	Thermomètre sous terre.
1830.	
Décembre le 16 à 8 h.m.	23°·8 C. .. 74°·8 F.
le 19 8	23·7 .. 74·6
le 22 9	23·7 .. 74·6
le 22 11	23·7 .. 74·6
9 h.s.	23·6 .. 74·5
10	23·6 .. 74·5

"Pendant les mois de janvier et février 1831, le thermomètre a toujours indiqué de 23°·6 à 23°·7 C. (74°·5—74°·6 F.).

Puracé

"Dans la Troja del Cura, élevée de 2,651 mètres (8,698 feet) au-dessus de la mer, le thermomètre a été placé dans le sol à 1 pied de profondeur.

	Thermomètre sous terre.
1831.	
Avril le 17 à 11 h.m.	13°·1 C. .. 55°·6 F.
midi.	13·1 .. 55·6
2	13·1 .. 55·6
4 h.s.	13·1 .. 55·6
le 18 8 h.m.	13·1 .. 55·6
9	13·1 .. 55·6

* * * * * * * *

The temperatures observed at 6 A.M., noon, and 6 P.M., from the 22nd of May to the 13th of July 1849, in each of three holes;* and at 3, 6, and 9

Quito.

"La température moyenne de Quito,—élevée de 2,914 mètres (9,560 feet)—a été fixée par deux observateurs, MM. les colonels Hall et Salaza; leurs observations donnent une température moyenne de 15°·55 C. (60° F.).

"Pendant mon séjour à Quito, j'engage ai M. Salaza à suivre la marche de son thermomètre mis à 1 pied au-dessous de la surface du sol. Les observations furent faites dans une salle Casse.

Mois.	Dates	Thermomètre.							
		à 7 h. m.		à 11 h. m.		à 2 h. s.		à 4 h. s.	
1331. Septembre	26	15°·5 C.	59°·9 F.	15°·5 C.	59°·9 F.	15°·5 C.	59°·9 F.	15°·5 C.	59°·9 F.
	27	15·5	59·9	15·5	59·9	15·3	59·5	15·5	59·9
	28	15·3	59·5	15·5	59·9	15·5	59·9	15·5	59·9
	29	15·5	59·9	15·5	59·9	15·5	59·9	15·5	59·9
	30	15·5	59·9	15·5	59·9	15·5	59·9	15·5	59·9
Octobre	1	15·3	59·5	15·5	59·9	15·5	59·9	15·5	59·9
	2	15·5	59·9	15·5	59·9	15·5	59·9	15·5	56·9
	3	15·4	59·7	15·5	59·9	15·4	59·7	15·5	59·9
	4	15·5	59·9	15·5	59·9	15·5	59·9	15·5	59·9
	5	15·5	59·9	15·4	59·7	15·5	59·9	15·5	59·9
	6	15·5	59·9	15·5	59·9	15·5	59·9	15·5	59·9
	7	15·4	59·7	15·5	59·9	15·5	59·9	15·5	59·9

"Les observations que je viens de rapporter établissent, ce me semble, d'une manière certaine, que la température moyenne d'un lieu abrité situé entre les tropiques, est donnée par la température du sol prise à 1 pied de profondeur."

BOUSSINGAULT, *Annales de Chimie et de Physique*, LIII. pp. 228—35.

"La temperature de Rio-Janeiro a été evaluée, par M. E. Chevalier (*Voyage de la corvette 'la Bonite,'* p. 18), à 24°·2 C. (75°5 F.) d'apprès des observations faites à 1 pied de la surface du sol et à la profondeur de 3 mètres (9·8 feet), dans un puits."—D'ARCHIAC, *Histoire des progrès de la Géologie*, I. p. 88.

* Trevandrum is situate in Long. 5° 7′ 59″ E., Lat. 8° 30′ 32″ N.; the Observatory hill, which exposes a grassy surface, rises to about 200 feet above the sea, is composed of the stone called *Laterite*, and in this thermometers were placed at the respective depths of 3, 6, and 12 French feet (3·2, 6·4, and 12·8 feet English measure).

A.M., noon, 3, 6, and 8 P.M., and midnight, from the 1st of January to the 13th of July, at the surface, are compared in *Table XXXVII.*; whilst the highest, lowest, and mean temperatures during intervals of ten days each, in the same periods as shown in *Pl. VI.* and in the following columns.

The following columns contain the monthly means of observations made daily (except on Sundays) at 6 A.M., noon, 6 P.M., and midnight, as well on each of these thermometers as on others at the surface, from the 1st of May 1842, to the 31st of December, 1845.

Months.	Surface.	3 French, 3·2 English, feet.	6 French, 6·4 English, feet.	12 French, 12·8 English feet.
January ..	78°·930	84°·954	85°·618	85°·528
February ..	80·386	86·838	86·625	85·784
March	82·730	88·789	88·110	86·373
April	83·370	89·614	88·527 *a*	86·916
May	81·603	88·413	88·224 *b*	—
June	79·023	85·012	86·883	86·878 *b*
July	78·450	83·250	85·144	86·537
August ..	78·990	83·566	84·736	85·894
September .	79·973	84·575	85·133	85·633
October ..	79·076	84·722	85·632	85·680
November .	79·750	84·622	85·271	85·651
December .	78·030	84·228	85·303	85·607
Means ..	80·025	85·715	86·264	86·043

The following conclusions are plainly discernible;—

The temperature of the ground at Trevandrum is from 5° to 6° higher than that of the air;—the principal maximum temperature of the *air* occurs about the beginning of April, and the extreme range is passed through in three months, the principal minimum occurring about the middle of July, the remaining fluctuations indicate a slight maximum about the middle of October The epochs of temperature are retarded with the depth below the surface, and, at the same time, the ranges diminish and casual fluctuations disappear.

CALDECOTT, *Edin. Phil. Trans.*, XVI. pp. 379—93.

a For two years. *b* For one year only.

Periods.	the surface.			Temperatures observed at depths of three feet.			six feet.			nine feet.		
	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.	Highest.	Lowest.	Mean.
1849.	°	°	°							°	°	
Jan. 1 — 10....	83·	65·	72·3									
„ 11 — 20....	84·3	61·	73·7									
„ 21 — 30....	84·8	62·	73·5									
„ 31 — Feb. 9.	79·5	63·	70·4									
Feb. 10 — 19....	81·5	56·	69·									
„ 20 — Mar. 1.	80·5	60·	73·									
Mar. 2 — 11....	80·5	64·	71·5									
„ 12 — 21....	78·	57·	68·9									
„ 22 — 31....	80·5	62·	70·									
April 1 — 10....	80·	62·	71·1									
„ 11 — 20....	77·	61·	68·4									
„ 21 — 30....	76·5	54·	65·1									
May 1 — 10....	70·	42·	59·3									
„ 11 — 20....	71·8	44·	61·9									
„ 21 — 30....	72·7	48·	61·5	73·7	72·1	72·8	71·6	70·6	71·3	71·8	71·1	71·4
„ 31 — June 9.	69·	50·	61·2	72·3	71·4	71·9	71·6	71·2	71·4	71·6	71·3	71·5
June 10 — 19....	73·4	43·	59·3	72·5	71·7	72·1	71·8	70·8	71·1	71·2	71·	71·1
„ 20 — 29....	70·2	50·	62·1	72·	71·1	71·5	71·2	70·8	71·	71·1	70·8	71·
„ 30 — July 9.	67·5	48·	57·7	71·9	71·1	71·5	..	..	..	71·	70·8	70·9
July 10 — 13....	68·	48·	57·8	71·3	71·2	71·3	..	..	..	70·8	70·7	70·8
January 1st to June 29th, Extremes	84·8	..	..	73·7	..	..	71·6	..	..	71·8		
	..	42·	..	..	71·1	..	..	70·6	..	..	71·	
Means	..	..	67·3	..	..	72·1	..	..	71·2	..	..	71·2
Ranges ..	42·8			2·6			1·			0·8		
January 1st to July 13th, Extremes	84·8	..	..	73·7	..	..	..	..	..	71·8		
	..	42.	..	..	71·1	..	..	..	..	..	70·7	
Means	..	..	66·3	..	..	71·9	..	..	..	..	..	71·1
Ranges ..	42·8			2·6			..			1·1		

At Brussels the temperatures hereafter mentioned are the means of ob-

From the 22nd of May to the 13th of July 1849, therefore, the extremes, the means, and the ranges of temperature were;—

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servations at different depths on opposite sides of the Observatory; from 1834 to 1839.

Months.	South of the Observatory.—Unshaded. Surface, Noon. 4 years.	Depths. 0·15 Mètre (0·49 foot). 2 years.	0·40 Mètre (1·31 foot). 1·35 year.	0·60 Mètre (1·96 foot). 4 years.	0·80 Mètre (2·63 feet). 4 years.	1 Mètre (3·28 feet). 2 years.	North of the Observatory.—Shaded. Surface. 6 years.	Depths. 0·19 Mètre (0·58 foot). 6 years.	0·45 Mètre (1·47 foot). 6 years.	0·75 Mètre (2·46 feet). 6 years.	1 Mètre (3·28 feet). 5 years.	3·9 Mètres (12·8 feet). 5 years.	7·9 Mètres (25·6 feet). 5 years.
Jan.	36°·7	34°·	34°·2	37°·1	38°·2	38°·5	37°·	38°·9	40°·6	42°·1	44°·3	53°·4	54°·5
Feb.	39·	34·6	34·3	36·8	37·8	39·	38·7	38·7	39·8	41·	43·7	51·6	54·
March	45·5	39·3	40·2	39·7	39·9	40·6	41·5	40·9	41·5	42·2	44·	50·2	53·4
April	51·3	42·6	43·9	43·1	42·9	42·8	44·6	43·1	43·3	43·6	45·	49·6	52·8
May	65·7	53·4	54·6	51·3	50·2	49·5	53·5	50·4	50·	49·3	49·5	49·8	52·2
June	72·4	60·8	60·6	60·2	58·4	58·4	62·	58·3	57·4	56·	55·7	50·9	51·9
July	74·	63·1	66·3	64·6	63·2	64·8	64·8	60·8	60·5	59·7	59·5	53·4	52·1
August ..	71·4	60·3	67·	63·4	62·3	64·9	63·1	60·3	60·5	60·5	60·9	55·6	52·6
Sept.	62·	57·8	58·6	59·	58·9	59·9	58·1	56·4	57·5	58·	59·1	57·1	53·3
Oct.	55·1	52·6	53·6	54·3	54·9	55·4	51·3	51·9	53·6	54·8	56·4	57·6	54·
Nov.	44·	44·6	43·7	46·	47·2	46·8	42·7	44·5	46·4	48.4	50·7	57·	54·5
Dec.	39·4	39·9	40·	42·	42·7	44·4	38·9	41·5	43·1	45·	47·3	55·4	55·
Means ..	54·7	48·6	49·8	49·8	49·7	50·4	49·7	48·8	49·5	50·	51·3	53·5	53·3

The following columns show the times of lowest, highest, and mean temperature;—at the surface and at various depths;—under both southern and northern aspects;—

Place of observation.	Extremes.	Means.	Ranges.
Surface	43°· —73°·4	59°·1	30°·4
Three feet deep..	71·1—73·7	72·1	2·6
Six „ „ ..	70·6—71·6	71·2	1·
Nine „ „ ..	71· —71·8	71·2	0·8

Depth.	Southern aspect.—Unshaded.				Northern aspect.—Shaded.			
	Lowest.	Spring mean.	Highest.	Autumnal mean.	Lowest.	Spring mean.	Highest.	Autumnal mean.
Surface	Jan. 13	Apr. 25	July 9	Oct. 20	Jan. 17	May 3	July 18	Oct. 21
Mètres. Feet.								
0·15 .. 0·49..	„ 14[a]	May 2	„ 9[a]	„ 30				
0·19 .. 0·58..	..	..	..	..	„ 29	„ 9	„ 24	„ 26
0·40 .. 1·31..	Feb. 8[b]	..	Aug. 2[b]					
0·45 .. 1·47..	..	..	..	..	Feb. 5	„ 13	„ 30	Nov. 4
0·60 .. 1·96..	Jan. 30	„ 9	July 23	Nov. 2				
0·75 .. 2·46..	..	..	..	..	„ 17	„ 18	Aug. 6	„ 8
0·80 .. 2·62..	„ 30	„ 12	„ 25	„ 8				
1· .. 3·28..	„ 25[a]	„ 19[a]	Aug. 6	„ 4[a]	„ 27	„ 24	„ 9	„ 13
3·9 .. 12·8..	..	..	..	..	Apr. 20	July 17	Oct. 14	Jan. 10

Between the times at which the lowest, highest, and mean, temperatures, respectively, occur at the surface and at different depths, the hereafter mentioned periods, therefore, intervene :—

Surface							
Mètres. Feet.							
0·15 .. 0·49..	1 day[a]	7 days	..	10 days[a]			
0·19 .. 0·58..	..	..	..	..	12 days	6 days	6 days	5 days
0·40 .. 1·31..	25 days[b]	..	24 days[b]					
0·45 .. 1·47..	..	..	..	..	7 „	4 „	6 „	9 „
0·60 .. 1·96..	..	..	..	3 „				
0·75 .. 2·46..	..	..	..	..	12 „	5 „	6 „	4 „
0·80 .. 2·62..	..	10 „						
1· .. 3·28..	..	7 „[a]	4 „	2 „[a]	10 „	6 „	3 „	5 „
3·9 .. 12·8..	..	..	..	..	52 ..	53 „	66 „	58 „

Quetelet, *Memoires de l'Académie Royale de Bruxelles*, x. pp. 3—80, xiii. pp. 3—52. (Abridged.)

[a] One year only. [b] Two years only.

From the 22nd of May to the 13th of July, however, the extremes, means, and ranges were;—

At Greenwich observations have been made daily, for many years, on thermometers—at the surface and at depths of 1 inch, 3·2, 6·4, 12·8, and 25·6 English (3·, 6·, 12·, and 24· French) feet. "The soil [is composed] of beds of sand; of flint-gravel with a large proportion of sand; and of flints with a small proportion of sand, cemented almost to the consistency of pudding-stone. * * * [Those parts of the tubes which project above the surface] are protected by a wooden case or box fixed to the ground; the sides of the box are perforated with numerous holes, and it has a double roof. In the North face of this box is a large plate of glass through which the thermometers are read." The extremes and means observed during the years 1865, 1866, and 1867 have been;—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
					At the surface.							
	°	°	°	°	°	°	°	°	°	°	°	°
Highest	53·6	55·2	57·8	75·8	81·6	83·9	84·5	84·7	82·7	73·2	63·	54·3
Lowest	20·	30·3	33·1	44·	42·3	54·6	57·	56·1	50·9	45·	37·9	28·7
Mean	40·5	44·1	43·	57·8	61·9	69·1	69·8	68·2	67·	57·5	47·7	43·1
					At a depth of one inch.							
Highest	50·2	50·7	50·1	59·4	65·	69·5	77·1	70·6	70·5	63·2	56·8	51·9
Lowest	29·	31·2	35·1	43·8	45·2	57·5	56·8	55·7	52·1	46·6	39·	34·3
Mean	40·2	42·7	40·7	51·2	55·5	63·	64·6	62·8	61·7	54·2	46·6	43·3
					At a depth of 3·2 feet.							
Highest	46·	46·	45·3	51·8	57·2	61·6	63·8	63·7	64·4	61·5	53·4	48·9
Lowest	39·1	39·4	39·1	40·5	48·6	53·6	59·4	59·	57·	52·2	45·6	42·2
Mean	42·6	42·8	41·4	47·	52·1	58·1	61·5	61·1	60·8	55·9	49·7	45·8
					At a depth of 6·4 feet.							
Highest	49·3	47·8[b]	47·2[b]	49·2	53·2	57·6	60·1	60·2	61·4	58·3	55·6	52·
Lowest	44·2	45· [b]	44·4[b]	44·5	48·9	51·9	56·4	58·	57·7	55·	50·8	47·
Mean	46·7	46·7[b]	45·4[b]	47·2	50·7	54·8	58·4	59·3	59·7	56·5	53·3	49·7
					At a depth of 12·8 feet.							
Highest	51·6	49·7	48·6	47·7	49·5	51·8	54·4	55·6	57·	57·2	56·3	53·6
Lowest	47·6	45·8	45·	44·8	46·	48·9	51·8	54·	55·6	55·	53·1	50·2
Mean	49·7	47·9	46·9	46·5	48·1	50·4	53·2	55·1	56·1	56·1	54·5	52·2
					At a depth of 25·6 feet.							
Highest	52·6	52·	51·3	50·6	49·9	51·6	50·4	51·3	52·	52·6	52·9	52·9
Lowest	51·	50·2	49·3	48·6	48·	48·8	49·7	49·8	50·8	51·8	52·5	52.3
Mean	52·	51·2	50·4	49·7	48·9	49·6	50·1	50·6	51·5	52·2	52·7	52·6

[a] Two years only.

Place of observation.	Extremes.	Means.	Ranges.
Surface	43°· —73°·4	60°·1	30°·4
Three feet deep..	71·1—73·7	71·9	2·6
Nine „ „ ..	70·7—71·8	71:1	1·1

The intervals between the times of highest and of lowest temperatures at the surface and at different depths, are shown in the foregoing columns.

The highest, lowest, and mean temperatures, as well as the ranges at the surface and at various depths, were—

	Highest.	Lowest.	Means.	Ranges.
Surface	84°·7	20°	55°·8	64°·7
1 inch in depth .	77·1	29·	52·2	48·1
3·2 feet „ ..	64·4	39·1	51·6	25·3
6·4 „ „ ..	61·4	44·2	52·4	17·2
12·8 „ „ ..	57·2	44·8	51·4	12·4
25·6 „ „ ..	52·9	48·	50·9	4·9

Magnetical and Meteorological Observations at the Royal Observatory, Greenwich, 1865, pp. XLII.—III., CCLXXXIII.—VII.; 1866, pp. XLIII.—IV., CXCII.—VI.; 1867, pp. XLIV.—V., CCLXIII.—VII.

At and near Edinburgh observations were continued from 1837 to 1842 at depths of 3·2, 6·4, 12·8, and 25·6 (English) feet;—

on the Calton Hill, ... in porphyritic trap, at 350 feet above the sea;
in the Experimental Garden, „ sand , „ 70 „ „ ;
& at Craigleith, „ sandstone , „ 150 „ „ ;
with the undermentioned results;—

Depth.	Calton Hill.				Experimental Garden.				Craigleith.			
	Highest.	Lowest.	Means.	Ranges.	Highest.	Lowest.	Means.	Ranges.	Highest.	Lowest.	Means.	Ranges.
3·2 feet	56°·2	35°·7	45°·5	20°·5	57°·2	35°·1	46°·1	22°·1	55°·9	35°·4	45°·9	20°·5
6·4 „	52·3	39·7	45·8	12·6	54·6	38·6	46·4	16·	53·8	38·1	45·9	15·7
12·8 „	49·4	43·6	46·3	5·8	50·6	42·8	46·7	7·8	51·1	40·7	45·9	10·4
25·6 „	47·8	46·	46·8	1·8	48·2	46·	47·1	2·	48·5	43·8	46·	4·7

The mean temperature of the air, at surface..... was 45°·2
„ on an average of all the stations, at 3·2 feet deep „ 45·8
„ „ 6·4 „ „ 46·
„ „ 12·8 „ „ 46·3
„ „ 25·6 „ „ 46·7

FORBES, *Edin. Phil. Trans.*, XVI. pp. 194, 204,—7; *Proceedings of the Royal Society of Edinburgh*, I. pp. 223, 344*.

The depths at which the observations were made;—the mean temperature of each spot at the commencement of the series (on the 22nd of May, 1849);—and the nearest periods at which these were, respectively, the means of the climate; are shown in the following columns:—

Depth.	1849, 22nd May. Mean temperature, underground.	Nearest preceding day on which the mean of the climate approached most closely to the temperature underground.		Interval, days.
		Date.	Mean temp., surface.	
Three feet ..	73°·3	Mar. 3	74°·3	80·
Six „ *..	71·4*	Apr. 6	72·7	46·
Nine „ ..	71·6	Apr. 6	72·7	46·

At Upsal thermometers sunk 1·07 foot, 2·14 and 3·20 feet in the ground, and observed daily at six in the morning, two in the afternoon, and nine at night, showed temperatures of which the monthly means are set forth in the following columns:—

Times.		1·07 foot.	2·14 feet.	3·20 feet.
1833.	July	60°·54	59°·	56°·96
	Aug.	55·61	55·45	55·18
	Sept.	53·92	53·61	53·47
	Oct.	48·14	48·34	49·26
	Nov.	39·	40·31	42·20
	Dec.	33·45	35·18	37·
1834.	Jan.	29·28	31·24	32·72
	Feb.	31·31	31·96	32·43
	March	32·63	33·13	33 44
	April	38·04	37·43	36·93
	May	48·02	46·56	45·10
	June	56·67	54·50	52·32
Means		43·88	43·89	43·92

RUDBERG, *Ann. der Chem. und Physik de Poggendorff*, XXXIII. *Memoires de l'Académie Royale de Bruxelles*, X. p. 36. *Edin. New Phil. Journal*, XXIII., p. 345

* At Trevandrum the mean annual temperature was higher at six, than at either three or twelve, feet.—CALDECOTT, *Edin. Phil. Trans.*, XVI. p. 392.

The proportion of solar heat absorbed by the ground must, of course, depend, in some measure, on the nature of the surface.*

The following columns set forth the means of observations, at the surface, as well as at depths of three,

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"The observations from which the following table has been deduced were made at Alverton, near Truro, in 1852—3. * * * Four pits, about two feet deep and two feet wide, were dug in good healthy garden loam. [The first] was filled with yellow clay frem the clay-slate; [the second] with pure white sand, from the sand-bed at St. Agnes Beacon; [the third] with peat, almost pure vegetable matter, well worked before put into the pit; [the fourth] with garden loam. The bulb of the thermometers was placed 4 inches below the surface in the centre of each pit, and another thermometer was placed in the same manner under the short grass of the lawn. Each variety of soil was thus subject to the same drainage below and to the same influences above. The readings of the thermometers were made in the morning when the temperature of the soil was lowest, and again in the evening when it was highest * * * .

"Temperature of the air and of different kinds of soil, Alverton, near Truro.

Date.	Air. Mean temp.	Clay. Mean temp.	Siliceous Sand. Mean temp.	Peat. Mean temp.	Garden Loam. Mean temp.	Grass. Mean temp.
1852. Sept.	57°·7	56°·6	60°	57°·6	59°·6	60°·1
Oct.	51·1	50·1	50·	51·6	51·1	54·2
Nov.	50·9	46·1	49·1	50·2	50·2	52·2
Dec.	49·3	46·7	46·2	47·8	48·1	49·6
1853. Jan.	44·9	42·1	42·1	43·7	43·2	46·7
Feb.	37·	36·	34·6	37·4	36·8	40·8
March	44·4	41·1	40·4	42·2	41·3	45·2
April	50·5	49·9	50·	50·8	50·8	53·
May	53·4[a]	57·1	57·2	57·7	58·3	60·1
June	57·6	64·	63·9	63·5	65·1	67·3
July	60·5	63·1	63·	63·8	64·3	67·2
Aug.	60·5	62·	62·5	62·8	63·9	68·1
Annual Means ..	51·5	51·2	51·6	52·4	52·7	55·4

WHITLEY, *Bath and West of England Agricultural Journal*, III. pp. 12—15. (Abridged.)

[a] 1852.

six, and nine feet; at 6 A.M., noon, and 6 P.M., during the same period;*—

Place of observation.	6 A.M.				Noon.				6 P.M.				
	May.	June.	July.	Means.	May.	June.	July.	Means.	May.	June.	July.	Means.	General means.
Surface	57°·8	56°·8	51°·9	55°·5	56°·5	60°·3	64°·7	62°·5	63°	63°·2	61°·5	62°·6	60°·2
3 feet deep..	72·7	72·7	71·5	72·3	72·7	71·9	71·4	72·0	72·6	71·8	71·4	72·	72·1
6 „ „ ..	71·2	71·2	—	71·2	71·2	71·1	—	71·2	71·2	71·	—	71·1	71·2
9 „ „ ..	71·3	71·4	70·8	71·2	71·4	71·2	70·8	71·1	71·4	71·1	70·7	71·1	71·1
Means, at 3, 6, and 9 feet deep	71·7	71·7	71·1	71·5	71·7	71·4	71·1	71·4	71·7	71·3	71·	71·4	71·5

It would seem, therefore, that at depths of three, six, and nine feet respectively, the mean temperatures slowly declined, both from May to July, and from morning to evening.† These observations, however, extend to neither of the annual extremes.

W. J. HENWOOD.

3, CLARENCE PLACE, PENZANCE.
1870, March 30th.

---

* Such observations only as were made simultaneously at the several stations, have been used in deducing these averages.

† At Trevandrum observations—at intervals of six hours—from the 1st of May 1842 to the 31st of December 1845, afforded the undermentioned results.

Depths.	Hours of observation.				Means.
	6 A.M.	Noon.	6 P.M.	Midnight.	
3 feet	82°·50	82°·66	82°·55	82°·50	82°·55
6 „	83·79	83·98	83·88	83·82	83·87
12 „	83·90	83·99	83·95	83·90	83·93
Means	83·46	83·54	83·46	83·41	83·45

CALDECOTT, *Bulletins de l'Académie Royale de Bruxelles*, IX. Partie I. pp. 303—10; *Proceedings of the Royal Society of Edinburgh*, I. pp. 432—3; *Edinburgh Phil. Trans.*, XVI. p. 391. (Abridged.)

EXPLANATION OF THE PLATES.

Copies of Working-plans and Sections of mines are marked with asterisks (*).

In the Plans *lodes* are represented by single, and *cross-veins* by double, lines.

In Longitudinal Sections the darkest shades indicate the portions which have been removed.

CHILI.

Plate I.

Plan of the Mining District of Chañarcillo.

Plate II.

Longitudinal section of the *Colorada lode*, Chañarcillo.†

BRAZIL.

Plate III.

Bird's-eye view of the gold-formation at different depths in *Morro Velho*.*

Plate IV.

Fig. 1*. Plan of *Gongo Soco*.
„ 2*. Longitudinal section of the *Gongo* gold-formation.
„ 3*. „ „ *Cumba* „ .
„ 4. Transverse section of the strata.‡

CORNWALL.

Plate V.

Fig. 1*. Plan of *West Caradon*.
„ 2*. „ *South Caradon*.
„ 3*. „ *Wheal Trelawny*.
„ 4*. „ *Wheal Mary Ann*.

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† Drawn from survey by Edwin Price Waring, Esq., Superintendent of *Colorada*.
‡ „ „ Captain John Luke of *Gongo Soco*.

A.M., noon, 3, 6, and 8 P.M., and midnight, from the 1st of January to the 13th of July, at the surface, are compared in *Table XXXVII.*; whilst the highest, lowest, and mean temperatures during intervals of ten days each, in the same periods as shown in *Pl. VI.* and in the following columns.

The following columns contain the monthly means of observations made daily (except on Sundays) at 6 A.M., noon, 6 P.M., and midnight, as well on each of these thermometers as on others at the surface, from the 1st of May 1842, to the 31st of December, 1845.

Months.	Surface.	3 French, 3·2 English, feet.	6 French, 6·4 English, feet.	12 French, 12·8 English feet.
January ..	78°·930	84°·954	85°·618	85°·528
February ..	80·386	86·838	86·625	85·784
March	82·730	88·789	88·110	86·373
April	83·370	89·614	88·527 *a*	86·916
May	81·603	88·413	88·224 *b*	—
June	79·023	85·012	86·883	86·878 *b*
July	78·450	83·250	85·144	86·537
August ..	78·990	83·566	84·736	85·894
September .	79·973	84·575	85·133	85·633
October ..	79·076	84·722	85·632	85·680
November .	79·750	84·622	85·271	85·651
December .	78·030	84·228	85·303	85·607
Means ..	80·025	85·715	86·264	86·043

The following conclusions are plainly discernible;—

The temperature of the ground at Trevandrum is from 5° to 6° higher than that of the air;—the principal maximum temperature of the *air* occurs about the beginning of April, and the extreme range is passed through in three months, the principal minimum occurring about the middle of July, the remaining fluctuations indicate a slight maximum about the middle of October The epochs of temperature are retarded with the depth below the surface, and, at the same time, the ranges diminish and casual fluctuations disappear.

CALDECOTT, *Edin. Phil. Trans.*, XVI. pp. 379—93.

a For two years. *b* For one year only.

Periods.	Temperatures observed at the surface. Highest.	Lowest.	Mean.	depths of three feet. Highest.	Lowest.	Mean.	six feet. Highest.	Lowest.	Mean.	nine feet. Highest.	Lowest.	Mean.
1849.	°	°	°									
Jan. 1 — 10....	83·	65·	72·3									
„ 11 — 20....	84·3	61·	73·7									
„ 21 — 30....	84·8	62·	73·5									
„ 31 — Feb. 9.	79·5	63·	70·4									
Feb. 10 — 19....	81·5	56·	69·									
„ 20 — Mar. 1.	80·5	60·	73·									
Mar. 2 — 11....	80·5	64·	71·5									
„ 12 — 21....	78·	57·	68·9									
„ 22 — 31....	80·5	62·	70·									
April 1 — 10....	80·	62·	71·1									
„ 11 — 20....	77·	61·	68·4									
„ 21 — 30....	76·5	54·	65·1									
May 1 — 10....	70·	42·	59·3									
„ 11 — 20....	71·8	44·	61·9									
„ 21 — 30....	72·7	48·	61·5	73·7	72·1	72·8	71·6	70·6	71·3	71·8	71·1	71·4
„ 31 — June 9.	69·	50·	61·2	72·3	71·4	71·9	71·6	71·2	71·4	71·6	71·3	71·5
June 10 — 19....	73·4	43·	59·3	72·5	71·7	72·1	71·8	70·8	71·1	71·2	71·	71·1
„ 20 — 29....	70·2	50·	62·1	72·	71·1	71·5	71·2	70·8	71·	71·1	70·8	71·
„ 30 — July 9.	67·5	48·	57·7	71·9	71·1	71·5	..	..	..	71·	70·8	70·9
July 10 — 13....	68·	48·	57·8	71·3	71·2	71·3	..	..	..	70·8	70·7	70·8
January 1st to June 29th. Extremes	84·8	..	..	73·7	..	..	71·6	..	..	71·8		
	..	42·	..	..	71·1	..	..	70·6	..	..	71·	
Means	..	..	67·3	..	..	72·1	..	..	71·2	..	..	71·2
Ranges ..	42·8			2·6			1·			0·8		
January 1st to July 13th. Extremes	84·8	..	..	73·7	..	..	..	..	..	71·8		
	..	42.	..	..	71·1	..	..	..	..	..	70·7	
Means	..	..	66·3	..	..	71·9	..	..	..	..	..	71·1
Ranges ..	42·8			2·6			..			1·1		

At Brussels the temperatures hereafter mentioned are the means of ob-

Fig. 27. *South Cliff Mine.* Minute grains of native copper and trap in a vein of prehnite traversing trap-rock.

„ 28. *Douglas Houghton (Henwood) Mine.* Longitudinal Section of the Works.

„ 29. „ „ . Grooved surface of vein-stone and native copper.

CHANNEL ISLANDS.

„ 30. *Sark's Hope Mine.* Longitudinal Section of the works.

IRELAND.

„ 31. *Knockmahon Mine; Stage lode.* Longitudinal Section of the works.

CORNWALL.

„ 32. *Wheal Trelawny.* Section of a concretion imbedded in clay-slate.

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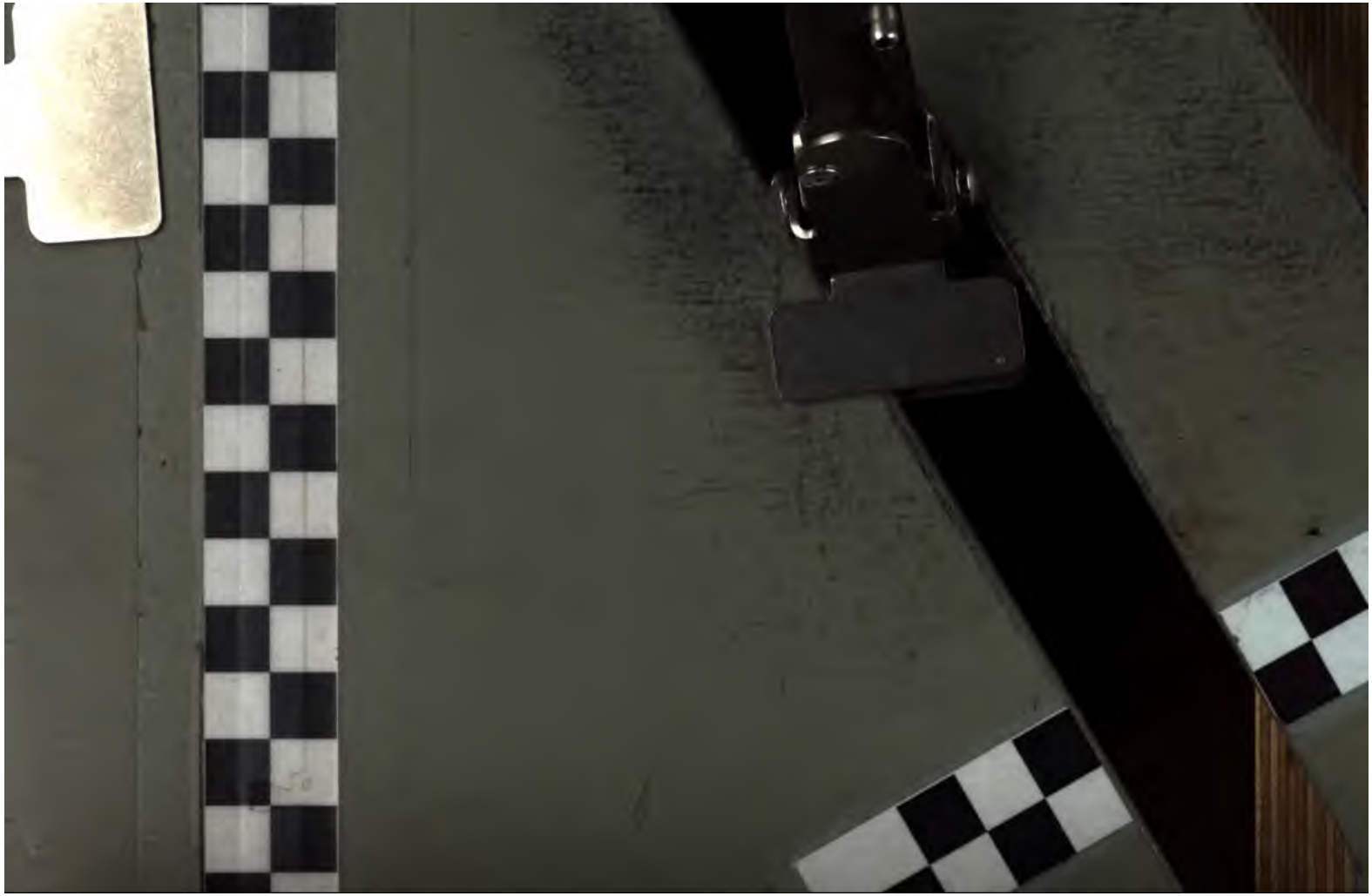
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